ANALYSIS OF U.S. AIR FORCE ADMINISTRATIVE LEAD TIME FOR PROCURING AIRCRAFT SPARE PARTS

THESIS

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Requirements for the Degree of

Master of Science in Systems Management

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"The day you stop learning is the day you become useless to the Air Force." - Frank Zuech

I would like to thank Major Kenneth Bauer, my thesis advisor. He taught me SLAM, guided me through the experimental design procedures, and with his inputs, helped make this document what it is now.

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Finally, I would like to thank my wife Marie for her support, understanding, and especially for doing more than her fair share of taking care of our newborn Christina.

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Abstract

The purpose of this research was to describe the spare parts procurement process at Ogden ALC/ UT in terms of adminstrative lead time. Specifically, this research describes the process from MMILBB to either PMWFW or PMWFL. The process was described in three ways. A flow chart depicting the flow of paperwork and associated activity times was constructed. This was translated into a SLAM network diagram and then into SLAM computer code. The computer code was used to experiment with the procurement system by varying the activity times and branching probabilities. The important parameters were then used to construct a metamodel, an equation that describes the SLAM model of the procurment system. Within MM, the metamodel is sensitive to the percentage of Forms 761 that need to be updated, to MIPR Control activity time, to the percentage of PRs going to PMWFW instead of PMWFL, and to the percentage of PRs under $100K going to PMWFW. Within PM, the metamodel is sensitive to activity time in PMWFW for PRs over $100K.

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I. Introduction

General Issue

The process by which the Air Force procures spare parts was changed due to the Competition in Contracting Act of 1984 (CICA). It was changed by including an organization created to meet the legislated requirement of establishing a Competition Advocate (22:1197). Within Air Force Logistics Command, the organization is the Directorate of Competition Advocacy. GAO Report 86-52 states:

> Our analysis indicated that DOD's emphasis on competition and quantity is well placed. Available data suggests (sic) that increased competition and quantities tend to reduce the prices paid for spares. Of course, there are other issues that have to be considered. These are:... If the services and DLA take longer to buy spare parts, the increase in pipeline time is a significant cost that will have to be considered. (15:27)

While the benefits of competition in terms of dollars saved may be more easily measured, the associated costs in terms of longer lead times are more elusive.

The procurement process is time consuming and complicated. There are many activities accomplished by

many people in many organizations. To manage and control the process, it is necessary to understand and measure it.

Specific Problem Statement

Which activities are the primary determinants of administrative lead time?

Research Objectives

1. Model the procurement process.

   a. Determine the flow of the various documents used in the procurment process.

   b. Determine the activity times of the procurement process.

2. Perform a sensitivity analysis on the model to find the primary determinants of administrative lead time.

3. Construct a linear metamodel of the procurement simulation.

Limitation of Scope

This research will study the spares acquisition process used by Ogden Air Logistics Center of AFLC. Additionally, this research follows the process on a path from only one of many possible starting points to only two of several possible finishing points. The basic flow is indicative of the process throughout the Center, but the activity times and branching percentages are only indicative of the researched path.

List of Acronyms

AFLC	Air Force Logistics Command
ALC	Air Logistics Center
ALT	Administration Lead Time
CR	Directorate of Competition Advocacy
DLA	Defense Logistics Agency
DO-41	Computer System - monitors recoverable/reparable items
DS	Directorate of Distribution
ES	Equipment Specialist
GAO	General Accounting Office
IMS	Item Management Specialist
J&A	Justification and Authorization
MIPR	Military Interdepartmental Purchase Request
MM	Directorate of Materiel Management
PERT	Program Evaluation and Review Technique
PM	Directorate of Contracting and Manufacturing
PMC	Procurement Method Code
PR	Purchase Request
SAS	Statistical Analysis System
SLAM	Simulation Language for Alternative Modeling

II. BACKGROUND

Description of the Data-Producing Situation

The Air Force receives spare parts primarily from two sources. Parts common to all military services are purchased and distributed by DLA. Parts unique to a service are purchased and distributed by that service. In the Air Force, that responsibility is delegated to AFLC. Within AFLC, that responsibility is delegated among five ALCs. Parts are categorized and assigned to an ALC by weapon system or common function, e.g. F-15, MX missile, or jet engines.

Each ALC has the same basic structure. MM is responsible for meeting customer demand for spare parts. PM procures what MM requests them to procure. CR advocates competition in the procurement. DS receives the parts from the contractor and stores them until MM authorizes distribution to a customer.

This research will study Ogden ALC which is responsible for spare parts on F-4 and F-16 aircraft, Minuteman and Peacekeeper missiles, landing gear components, and other systems. In particular, this research will study the procurement of landing gear components.

The acquisition process begins with one of the monitoring computer systems; reference the Summary Flow Chart, Figure 1. The monitoring computer system, the

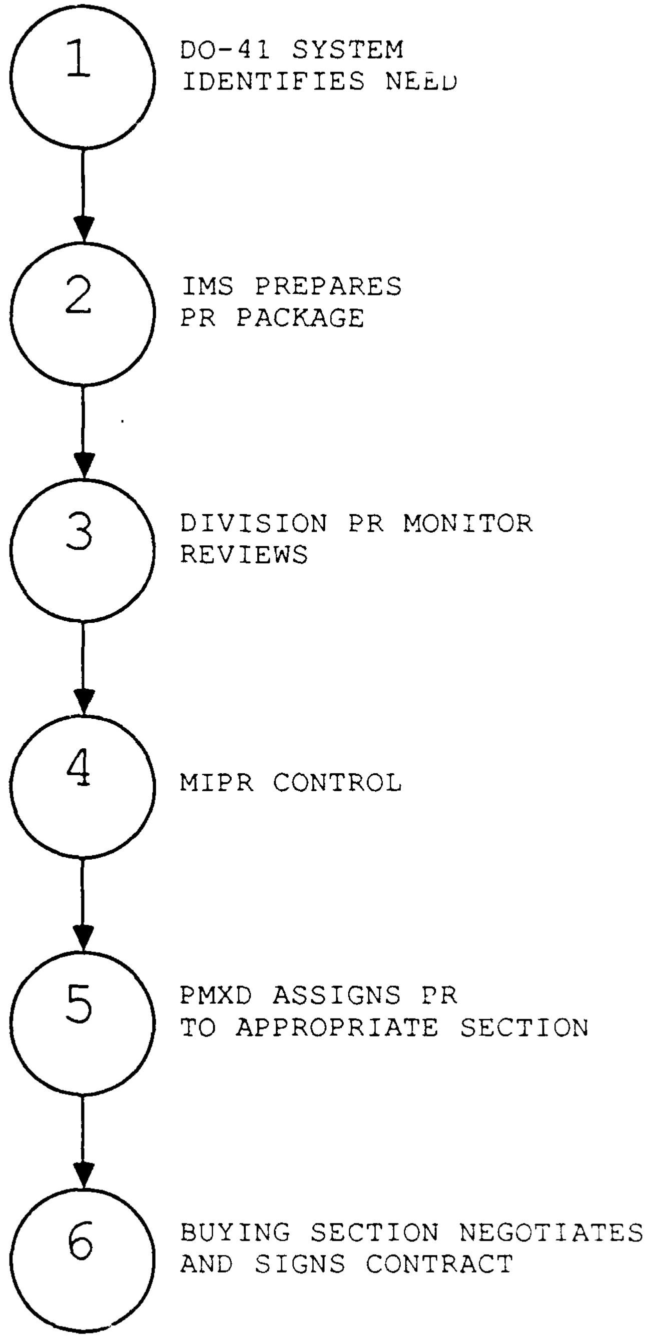

Figure 1: Summary Flow Chart

DO-41 for the purposes of this research, indicates to the IMS extra quantities of some item need to be purchased. The IMS prepares a PR package and sends it to the division's PR monitor. The PR monitor then sends the PR package to PR/MIPR Control, the central control point for the entire MM. PR/MIPR Control then sends the PR package to PMXD. PMXD assigns the PR to a buying section. A buyer in the buying section either solicits bids or negotiates a contract and signs it.

Generalizability. The model created as a result of this research is comprised of two elements. First is the description of the flow of paperwork necessary to transform a requirement into a contract. The description is generalizable to Ogden ALC. The second element is the parameterization of that flow i.e., assigning activity times and branching probabilities. The parameterization is not fully generalizable to Ogden ALC. For simplicity, the data collection started with a knowledgable IMS and followed the path a PR takes until the requirement is on contract. See Figure 2. The only portion of the parameterization generalizable to Ogden ALC are those parameters concerning PR/MIPR Control and PMXD; they are insensitive to the source and the destination of a PR, respectively.

Details of Data Collection. The people working in the process provided the data. The data includes the organizations involved, their interrelationships, task

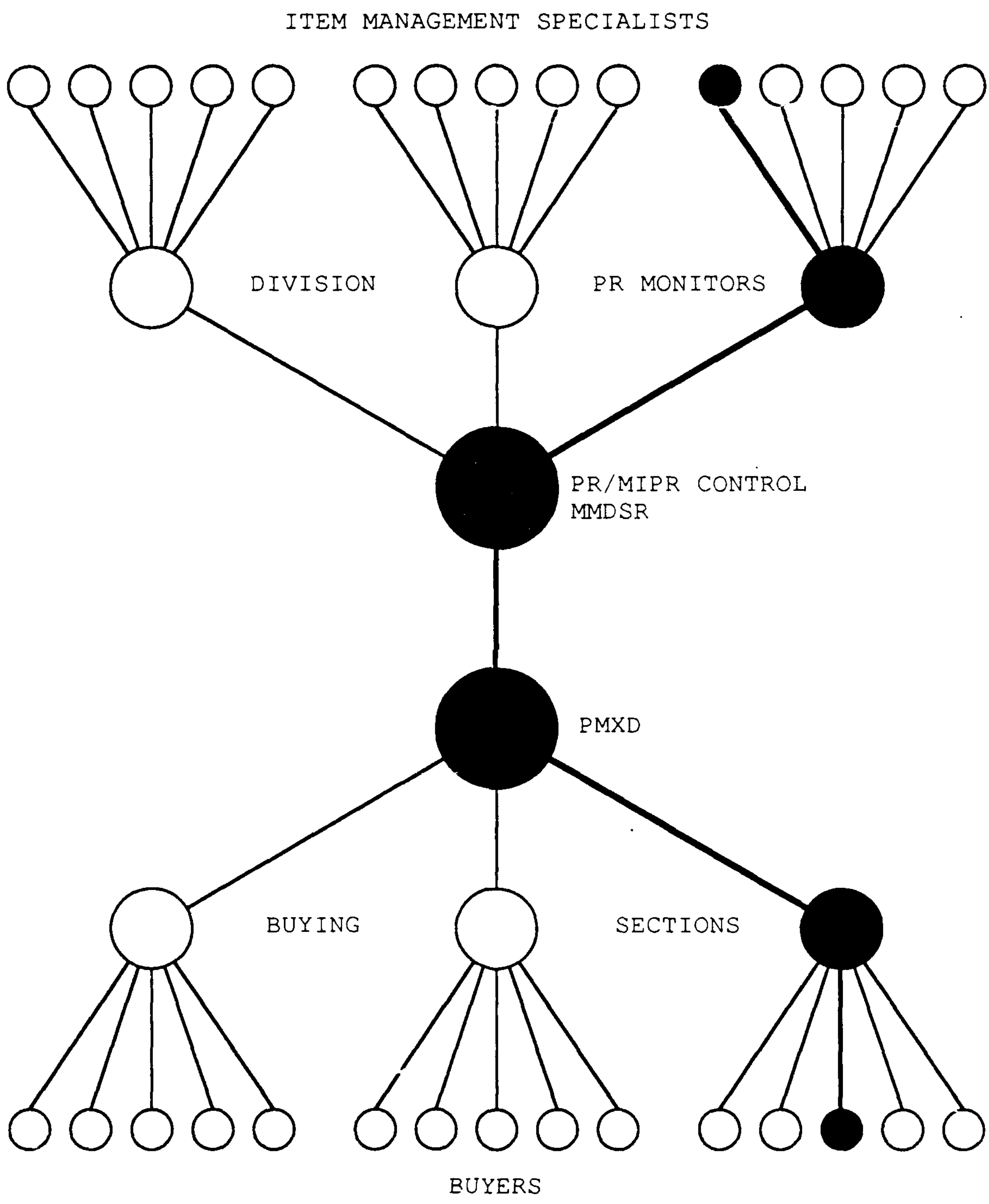

Figure 2: Acquisition Path Modeled

descriptions, and task durations. The people working in the process provided data initially via telephone interviews, and subsequently via personal interviews. See Appendix A for a list of those who provided the data.

Overview of the Analytical Model

The data will be analyzed in a PERT network of the acquisition process written in SLAM computer code. PERT allows for variability in both task duration and task path. It will show the relationships between tasks.

PERT. PERT is the management technique used in this research to describe the acquisition process. "PERT was developed to provide more intensive management of the Polaris missile project (21:484). PERT is an appropriate technique because the acquisition process is one "consisting of interdependent activities" (19:216), "the duration of the activities is not known with certainty" (23:328), and "it offers a way of dealing with random variation" of activity times (4:223). Moreover, PERT is appropriate since the acquisition process includes some activities that can only occur after some number of parallel activities have occured. Although PERT was developed for project management, it is useful in this case for process management.

Activities. "To apply PERT, we need a list of the activities that comprise the project" (23:329). Each activity in PERT is described by activity times and by its

position in the sequence of activities. PERT uses three time estimates: an optimistic time estimate, a most likely time estimate, and a pessimistic time estimate (1:113, 4:225, 19:706). The sequence of activities must accurately depict the actual acquisition process with its associated branches and nodes. "A project network is used to represent the precedence relationships between activities" (23:329).

Networks. "Networks provide a graphic display of the working plan needed to accomplish the project. They portray the planned sequence in which activities and events must occur as well as their interrelationships and interdependencies" (1:110).

A network of activities will have a critical path. The critical path is the path through the network that takes the most time. (1:114, 21:496). "The path is time critical because a delay in completing any of its activities delays the whole project" (21:496).

Corrective Actions. Once a manager has a complete PERT network, every activity on the critical path should be subjected to the following questions:

1. Is the sequence of the activity in a 'must' or in a 'desired' order? If in a 'desired' order, can the activity be sequenced in parallel with others on the critical path thus shortening the duration of the project? If it can, what added risk is being assumed? What is the effect on the availability and the allocation of resources?

2 Is the time estimate for the activity realistic? Can it be shortened by adding resources? Is this

> potential reduction in time worth the added risks and costs? (1:115)

PERT is a useful management tool to model either a planned or an existing system.

SLAM. SLAM is a computer language designed to let a model builder simulate the behavior of systems.

> A model is a representation of a system which can be used as an explanatory device, an analysis tool, a design assessor, or even as a crystal ball. Simulation languages provide a framework for building models on which experiments called simulations can be performed. Through the building of models and their analysis using simulation, decision making can be supported and improved. (19)

The SLAM network is a visual representation model and the computer language of the network is the simulation model for experimenting and analysis. Each SLAM statement in the computer language corresponds to the appropriate SLAM network symbol. A SLAM network is composed of activities and nodes. Properly constructed, the activities and nodes will act upon the entities travelling through the network the same way the system being modeled acts upon its entities.

SLAM is an appropriate language for the PERT network of the acquisition process. Pure PERT does not allow activities to have a probability of occurring less than one; SLAM allows such branching (19:125). SLAM has two especially useful nodes for PERT networks. The COLCT node collects statistics on five types of variables, including time to reach that node(19:136). "The ACCUMULATE or ACCUM node accumulates entities until a prescribed number is

reached. When the number is achieved, the node is released" (19:214).

III. Methodology

The purpose of this chapter is to describe the ten steps in this simulation study. The steps are those suggested by William E. Biles (3:7-8). The first two steps are "Problem formulation' and "Setting objectives", respectively. Since these two steps are essentially the problem statement, research objectives, and limitation of scope, they will not be included in this chapter.

Model Building

> - the process of capturing the essential features of a system in terms of its entities, the attributes or charactistics of each entity, the activities in which these entities engage, and the set of possible states in which the system can be found. (3:7)

The essential features of the system were determined in two phases. The first phase was by telephone interviews. The second phase was by personal interviews.

Telephone Interviews. The purpose of the telephone interviews was to determine the various activities necessary to complete the acquisition process and the organizations involved. The line of questioning was intended to follow a PR through the system.

IMS. The telephone interviews began January 6, 1989 with a call to LaVae Evans, a knowledgable and respected IMS (14). She said the process begins with a requirement generated by the DO-41. Every purchase request had to include an AFLC Form 338, an AFLC Form 807,

and a current AFLC Form 761. An AFLC Form 268 is required if the JO-23 needs updating. Additionally, there are two classes of PR, mechanized and manual. A mechanized PR is generated by preparing an AFLC Form 267. There are two ways to generate a manual PR. One way is to fill out an AFLC Form 36 by hand. The second way is to change a mechanized PR by hand and relabel it "MANUAL". In some cases, a J&A is required in the PR package. The PR package, consisting of AFLC Forms 761, 338, 807, either 36 or 267, and a J&A as required, is sent to the division PR monitor.

PR Monitor. On January 9, 1989, I spoke with Rick Chevez, the division PR monitor (9). He said he assigns a unique number to the PR. The competition manager looks at the J&A if one is included, and elevates the PR to get the proper signature level. A J&A panel review is required if the value of the PR is over one million dollars. If no J&A is required, the signature level is justified already by the DO-41 monitor. The PR packages get sent to MIPR Control.

MIPR Control. On January 10, 1989, I spoke with Elaine Caravan who works the PR packages at MIPR Control (7). She checks the dollar value, the J&A, and the PMC code to determine the appropriate coordination cycle. The final coordination step is to send the package to accounting to get funds committed. Lastly, the system is cleared and the package is sent to PMXD.

PMXD. On January 23, 1989, I spoke with Jerry Cook who receives the PR packages from MIPR Control (11). He receives the packages daily and matches a buying history and bidders list to each package. He stamps the date on the PR. The most imporant activity is to input "OO" card for the JO-18 computer system; this assigns the PR package to a buying section and gives them authority to purchase. Finally, he sends the PR packages to the appropriate buying section. Landing gear items, those with a stock class of either 1620 or 5330 with a "LE" suffix, go to PMWFL. Wheel and brake items, those with a stock class of either 1630 or 2620 with a "LE" suffix, go to PMWFW.

PMWFL. On January 31, 1989, I spoke with John Martinez, the section chief (17). He assigns PR packages based on the grade of the buyer (e.g., GS-11), dollar value, complexity, PMC code, and special team priorities. He has fourteen buyers to negotiate contracts and eight of them are also authorized to sign contracts.

PMWFW. On January 31, 1989, I spoke with Cal Cottrell, the section chief (12). He assigns PR packages based on whether they are sole source or competitive, and the dollar value. He has seven buyers to negotiate contracts and four of them are also authorized to sign contracts.

Personal Interviews. The personal interviews were an important step in this research. They were conducted the

week of June 19, 1989 at Ogden ALC. A flow chart of the acquisition process was constructed as a result of the telephone interviews. The personal interviews allowed some of the same people from the telephone interviews to look at the visual model and point out any mistakes in the model (13; 8; 10). A signficant change to the model was due to the information about the J&A coordination process provided by Connie Morrison (18). Extra detail about MIPR activities was provided by Sue Rose (20). Activitiy times for PMWFW and PMWFL were provided by William Cambell and Richard Lee, respectively (6; 16). By the end of the personal interviews, the reconstructed flow chart incorporated all the changes.

In this way, through a combination of telephone interviews followed by personal interviews, the essential features of the system were captured. The attributes of the entity are whether the PR is manual or mechanized, and whether the PR package includes a J&A or not. A detailed description of the revised model is given in chapter four.

Data Collection

> - gathering data and information which will allow the modeler to develop the essential description of each of the system entities, and developing probability distributions for the important system parameters. (3:7)

Two types of data were collected, branching probabilities and activity times. During the personal interviews, after the model had been revised, the people

involved in the process provided the branching probabilities and the activity times for those activities that take place within their respective scopes of responsibilities. The activity times usually took the form of a triangular distribution; seldom did they take the form of either a uniform distribution or a constant.

While this approach to branching simplifies the data gathering, it affects the generalizability. For instance, the IMS chosen for this research generates manual PRs only one percent of the time and changes a mechanized PR to a manual PR only fifteen percent of the time, while the division PR monitor sees manual PRs forty percent of the time.

Coding

> - the process of translating the system model into a computer program which can be executed on an available processor. (3:7)

With SLAM, coding is a two step process. The first step is to construct a SLAM network diagram. A SLAM network diagram was constructed using the revised flow chart, the branching probabilities, and the activity times. See Figures 3 and 4.

The second step is to translate the SLAM network diagram, with its associated activities and nodes, into SLAM code. Each activity and node can be directly translated into SLAM code. Each line of code in the network is either an activity or a node. Activities in

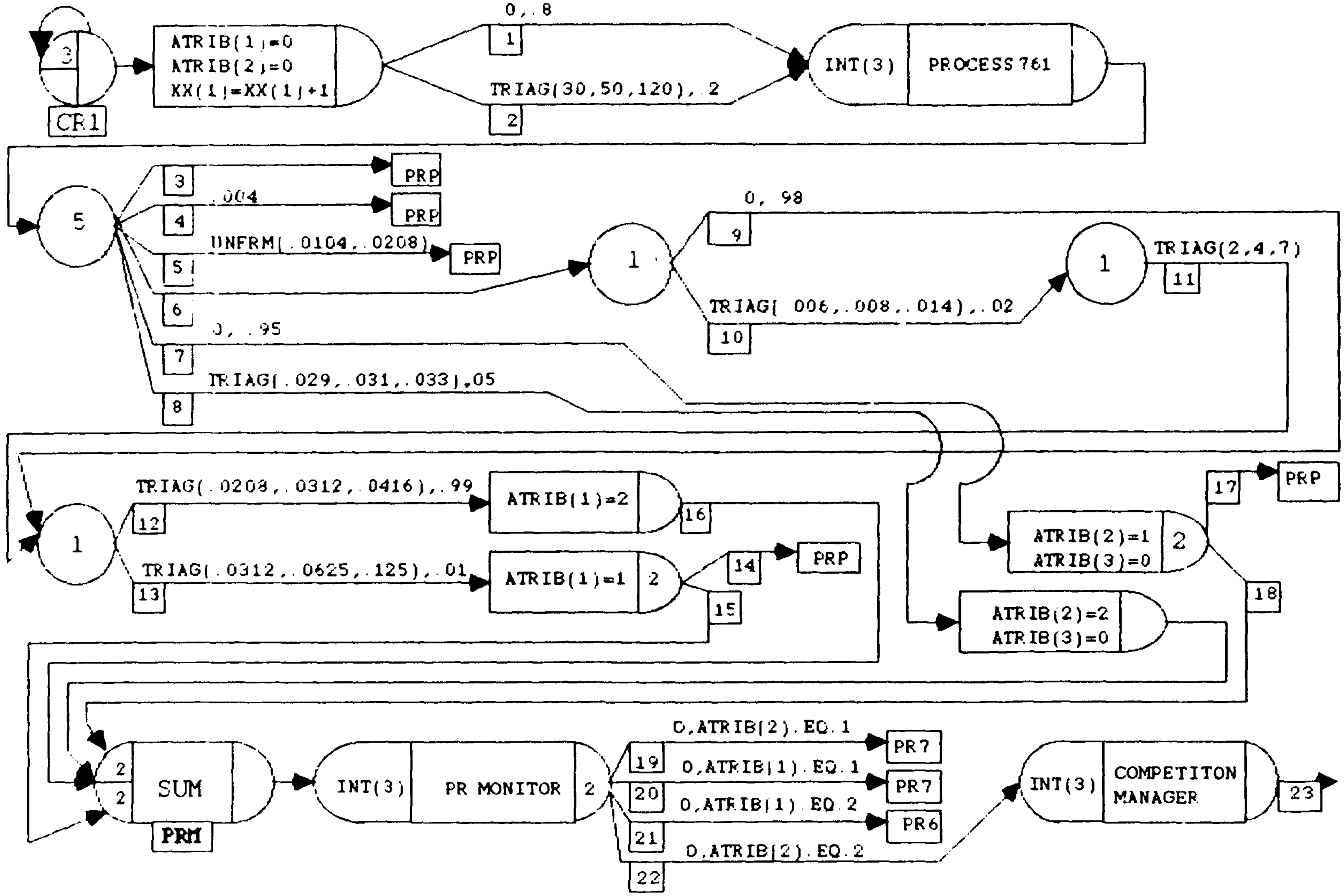

Figure 3 SLAM Network Diagram - Part A

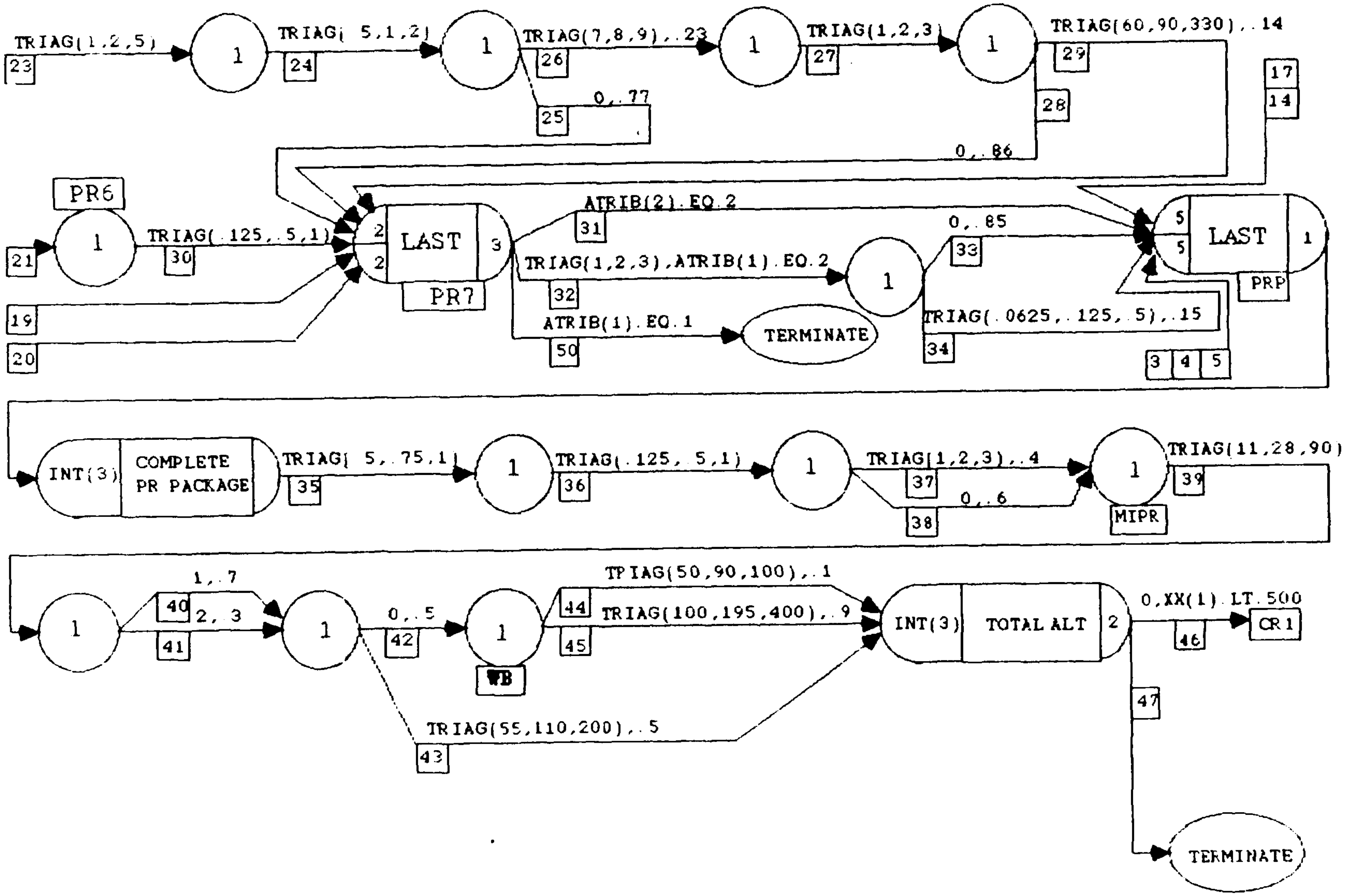

Figure 4: SLAM Network Diagram - Part B

SLAM code have an extra parameter to send the entity to a line in the code other than the next line. The basic SLAM model listing is in Appendix B.

SLAM may be executed either on a mainframe computer or on a personal computer. For this research, the SLAM model executed on a VAX 11/785 mainframe computer. One aspect of the code does not pertain to the system, but it facilitates multiple runs on the computer. A counter is kept in the global variable XX(40). As long as the value of XX(40) is less than the number of runs desired, 1500 for this research, an entity will be sent to the create node to repeat the process.

The SLAM code was written using the ENABLE word processor and saving the file in ASCII with a file name ending in ".dat". On a mainframe, get the SLAM menu of options by typing "RUNSLAM". The SLAM report will be written in [FILENAME].OUT. The personal computer version of SLAM has a batch file to simplify execution. To execute, type "SLAM2 [FILENAME]". The SLAM report is automatically written in [FILENAME].rpt. The batch file listing is in Appendix C.

Verification

> - the process of ascertaining that the computer program performs properly. (3:7)

The verification process used two statistics provided in the SLAM report. The first was the time it took to

reach the different nodes. The time was measured using the COLCT node and collecting the statistic of the difference between the current time and the time the entity entered the system. The time an entity enters the system is called its mark time. Initially, the times went from increasingly positive, as one would expect, to negative. The negative time occurred because at one of the ACCUM nodes, the attributes of the arriving entities were being summed including the attributes storing the mark time. This problem was remedied by setting to zero the attribute storing the mark time on one of the two entities going to that ACCUM node.

The second statistic used to verify the model was the number of entities passing through each activity. Initially, more entities exited the system than entered it. In the process of translating the flow chart to SLAM network diagram, dummy entities were created to send to the various ACCUM nodes. After a Form 36 is filled out, it is ready for the PR package. But since a Form 267 would not be filled out in that case, a dummy entity is sent to the ACCUM node waiting for a Form 267. Originally, the SLAM network diagram had both manual PRs and their dummies going to an ACCUM node that releases after five entities arrive. In the course of fifteen hundred runs, the extra entities accumulated and released more entities. This second problem was remedied by "filtering" out the dummy manual PR entities and

terminating them. Additionally, the activity counts served as a check by counting the entities passing through activities emanating from a decision branch; the count should equal the number of runs made.

Validation

> - the process of ascertaining that the model mimics the real system, by comparing the behavior of the model to that of the real system where the system can be observed, and altering the model to improve its ability to represent the real system. The combined steps of verification and validation are crucial to establishing the credibility of the model, so that decisions reached about the system on the basis of the simulation study can be supported with confidence. (3:7)

The visual model was validated during the week of June 19, 1989. By letting the people involved in the process make changes to the original flow chart, validation occurred iteratively. Additionally, the revised flow chart was shown to Karen Clark and Colleen Smith who work in MMDS. They are responsible for determining the flow within MM, and they approved of the model.

Moreover, they noted the model includes a nuance not included in a model they had seen from HQ AFLC. The nuance was the model included the possibility of an uncoordinated J&A being included with the PR package. See Figure 13. Because the IMS for this research never includes an uncoordinated J&A with a PR, this nuance appears neither in the SLAM network diagram nor the SLAM

computer code; it could, however, be easily included for the purposes of experimentation.

The computer model is validated by comparing its output to the data provided by Karen Clark and Colleen Smith. The data used for comparison with the model is in Appendix J. The following is a comparison of statistics on total administration lead time:

Table I: Comparison of Total ALT Statistics

SOURCE	MEAN	STD DEV	MIN	MAX
Model	230	84.8	87.3	524
Real System	264.4	69.34	114	490

The means of this statistic are so close a t-test comparing the difference of the means would not allow the hypothesis of no difference to be rejected for any reasonable rejection region. Therefore, we gain confidence the model is an adequate simulation.

The following is a comparison of statistics on administration lead time within MM:

Table II: Comparison of MM ALT Statistics

SOURCE	MEAN	STD DEV	MIN	MAX
Model	60.4	32.7	17.9	265
Real System	139.4	59.04	27	301

These differences can be attributed to the process time a package incurs before it reaches MIPR Control. The following is a comparison of statistics on administration

lead time within MM before the package reaches MIPR Control.

Table III: Comparison of Pre-MIPR ALT Statistics

SOURCE	MEAN	STD DEV	MIN	MAX
Model	19.2	30.3	1.2	246
Real System	102.4	54.44	10	264

The last comparison shows the variability in PR package processing time among the various divisions and among the various IMSs. The model is simulating one IMS and one division whereas the real system is measuring many IMSs from many divisions.

The differences in Tables II and III can be explained. The real system data is measuring times from different IMSs in different buying sections in different divisions in MM. They are buying different kinds of items so their activity times cannot be expected to be homogeneous. The model is simulating a PR with a faster than average MM ALT and a slower than average PM ALT with a total ALT within about a half of a standard deviation away from the mean of the real system.

Experimental Design

> - determining the alternatives that can be evaluated through simulation, choosing the important input variables and their appropriate levels, selecting the length of the simulation run and the number of replications. (3:7)

The strategic plan for experimental design has four steps (2:3). See Figure 5. The end result will be an equation, the metamodel, that describes the model of the procurement process.

Factor Screening. Factor screening is the screening of all the variables in the model to determine which are the primary determinants. The screening is done by running the model at different variable settings and computing the best estimate of the contribution of each variable. Those variables with a small contribution estimate are screened out.

The contribution estimates are computed by following Plackett and Burman's "DESIGN OF OPTIMUM MULTIFACTORIAL EXPERIMENTS" (2:138). The design works for several setting levels of each variable; two settings per variable were examined for this research. These settings were made to cause each variable to either increase ALT or decrease ALT. Plackett and Burman provide design matrices for various numbers of input factors. The design matrix determines the setting for each variable for each run of the model.

The design matrix is constructed using Plackett and Burman's Table of Designs (2:142). There are thirty-three variables under consideration. Find an "N" greater than or equal to the number of variables plus one; "N" equals thirty-six for this research. Following the "N" in the table, a series of pluses and minuses are listed and will

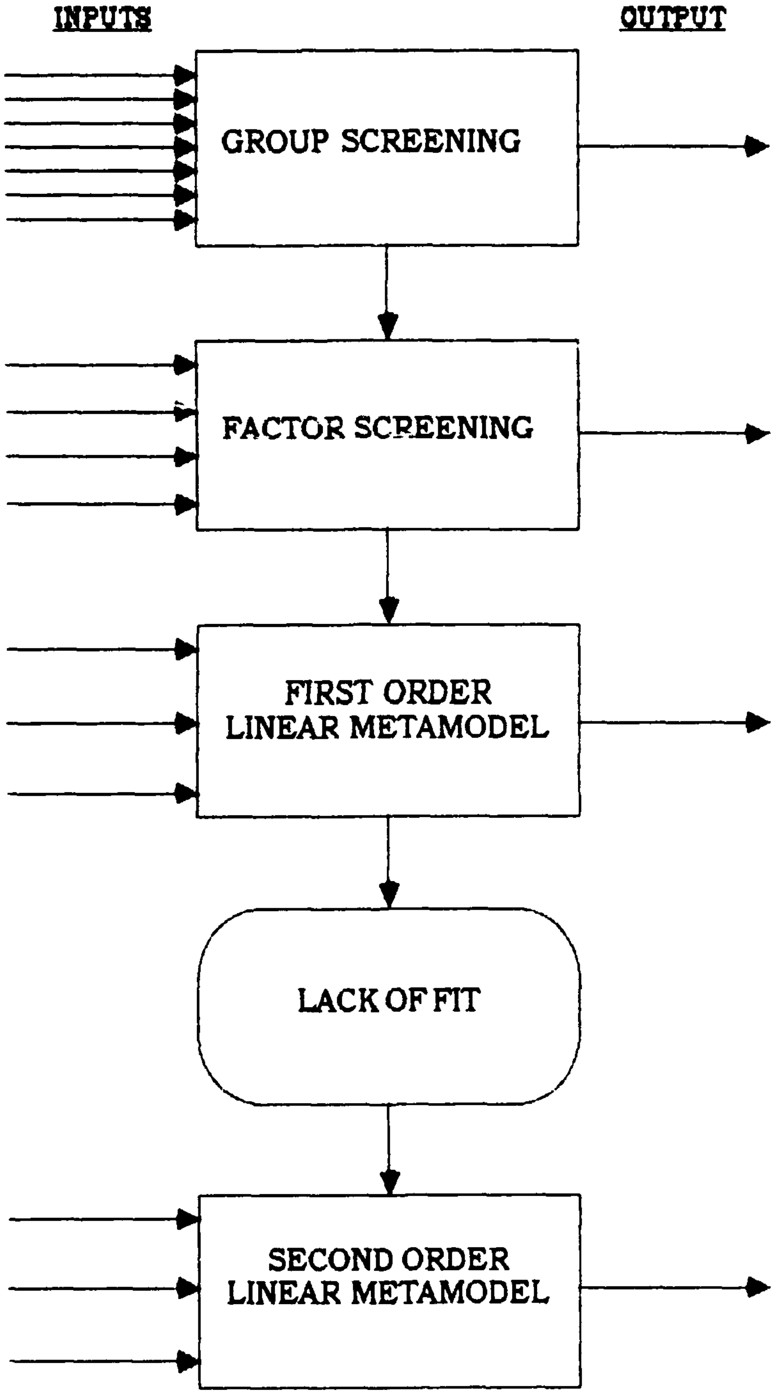

Figure 5: Strategic Plan (2:3)

number "N" minus one. Each column of the matrix will contain the series of pluses and minuses except the series in column (i) starts in row (i) and "wraps" around to fill in the top. This is easily constructed on a spreadsheet using first block copy commands to put all columns next to each other in a staggered fashion and then use block copy commands to move the bottom elements hanging over up to the top. The matrix is completed by adding a row of all minus ones; this results in "N" total rows. Each column is half pluses and half minuses. Each row of the matrix determines the high or low setting for each variable; the settings for variable (i) are in column (i). The thirty-three input variables under consideration are in the SLAM global variable XX(I) and I goes from one to thirty-three. A plus one is a variable setting to increase ALT and a minus one is a variable setting to decrease ALT. After "N" runs, "N" values are generated by the model; the values are of ALT for this research. See Appendices D and E for the listings. The run results are put in a single row matrix. The best estimate of each variable's contribution is computed by multiplying the matrix of run results times the design matrix and dividing each element of the resulting single row matrix by "N"; the resulting matrix will have one column for each variable.

First Order Linear Metamodel. In finding the first order linear metamodel, only the contributing variables

are varied. The runs are generated using a different design matrix. The design matrix is one for a fractional factorial design of resolution IV. With it, two-way interactions can be estimated clear of main effects (5:164). The size of the design matrix is determined by the number of variables and interactions of interest. For this research, seven factors and their twenty-one two-way interactions were screened. This requires twenty-eight columns. The number of rows must be a power of two i.e., 4, 8, 18, 32, etc. The number of rows must exceed the number of columns, so thirty-two rows were used in this research. The first column has pluses and minuses alternating one at a time. The second column has pluses and minuses alternating two at a time. The third, fourth, and fifth column are similar. The sixth column is the product of the first, second, third and fourth columns. The seventh column is the product of the first, second, third, and fifth columns. The columns for the two way interactions are the product of the two columns they represent e.g., the interaction of variable two and variable six is column two times column six. Only the first seven columns of the design matrix are used to generate ALT, the entire design matrix is used in the next step. Thirty-two runs were made to generate ALT; see Appendices F and G. Ten more runs were generated with all variable settings half way between the settings for plus and minus one.

Fitting the Metamodel. The metamodel is an equation that describes the model of the procurement process. The equation was determined using SAS routine PROC STEPWISE. SAS is on the VAX 11/785 and is accessed by typing "RUNSAS" and following the prompts. PROC STEPWISE determines which of the twenty-eight variables tested for this research are significant to the polynomial equation; insignificant factors are omitted from the equation by PROC Stepwise. See Appendix H.

Lack of Fit. The equation determined by PROC Stepwise must pass a test for lack of fit before the equation may be called the metamodel. See Appendix I. If the equation fails the lack of fit test, the fifth step is needed.

The lack of fit test was done on SAS using PROC RSREG. See appendix I. The design matrix was the same as that used for Factor Screening with the addition of ten runs with all variable settings equal to zero. The lack of fit test only works with repeated runs and those runs will not alter the coefficients of the equation.

Second Order Linear Metamodel. This step was not necessary because the first order linear equation passed the lack of fit test. Had it been necessary, a second order linear metamodel could have been found using PROC RSREG without using the COVAR=n option.

Production Runs and Analysis

> - assessing the effects of the chosen input variables on the selected measures of system performance, and determining whether more runs are needed. (3:7)

This step is essentially accomplished within the strategic plan of the experimental design.

Simulation Report

> - documenting the simulation program, reporting the results of the simulation study, and making commendations (sic) about the real system on the basis of the simulation study. The *implementation* of these recommendations is usually the result of a decision by the appropriate manager in the organization." (BILES:8)

This step is essentially the thesis itself. Specifically, conclusions and recommendations are in chapter five.

IV. Findings

Description of the Model

The model, its key to symbols, and its ensemble are in Figures 6 through 14.

IMS. The acquisition process begins with a requirement generated by one of the monitoring computer systems. For LaVae Evans, it is the DO-41. The first action by the IMS is to check and see if the file copy of the AFLC Form 761 for the item is current. See Figure 8. Each completed AFLC Form 761 has an expiration date and the IMS cannot allow the Form 761 to expire before the item is put on contract. To update a Form 761, the IMS prepares the form and sends it to CRED to be completed. CRED returns the completed Form 761 to the IMS.

Once the IMS has a current Form 761, the rest of the PR package elements may be processed. The two fastest and easiest elements are AFLC Form 338 and AFLC Form 807. The IMS fills out the multi-year contracting Form 338, and the IMS and the ES together fill out Form 807. See Figure 9. The Form 761 will indicate whether or not a J&A is required. When it is required, the IMS will prepare the J&A.

The most important element of the PR package is the PR. The first step in generating a PR is to check if the JO-23 computer system needs updating. See Figure 10. If it does, the IMS prepares an AFLC Form 268 and sends it to

the division PR monitor for processing. Once the JO-23 is upto date, the IMS decides whether to generate a manual PR or a mechanized PR. A manual PR is generated by filling out an AFLC Form 36. A mechanized PR is generated by preparing an AFLC Form 267 and sending it to the division PR monitor. The IMS will include a J&A with the Form 267 if one has been prepared. Also, in the case of a manual PR, the IMS will send just the J&A.

If the IMS includes a J&A, the division PR monitor will give the J&A to the competition manager to process while he processes the Form 267. See Figure 11. The competition manager checks the J&A for accuracy and completeness. If the PR is over one million dollars, she must conduct a J&A panel review. If not, the J&A needs to be signed at division level. After a panel review and if the PR is less than ten million dollars, the J&A needs to be signed at division level and at directorate level. If the PR is over ten million dollars, the J&A needs to be signed at division level, directorate level, and SECAF level. Meanwhile, the division PR monitor edits the Form 267 for completeness. When the competition manager returns the coordinated J&A to the division PR monitor and the Form 267 has been edited, the division PR monitor will assign a unique PR number to the PR. See Figure 12. Next, the division PR monitor will send the Form 267 to key punch to get entered into the computer system.

The IMS will receive twenty-four copies of the mechanized PR AFLC Form 306. At this point, the IMS may opt to make manual corrections to the Form 306. If manual corrections are made, the Form 306 must be labeled "MANUAL". Finally, the IMS has all the elements for a complete PR package. The IMS assembles a package consisting of Form 761, Form 338, Form 807, a J&A if required, and either Form 36 or Form 306. The package is sent to the branch chief. The branch chief coordinates on AFLC Form 338 and sends the PR package to the division PR monitor.

PR Monitor. The division Pr monitor checks the entire PR package for accuracy and completeness. See Figure 13. If the package includes a Form 36, the divison PR monitor assigns a PR number and writes it on the Form 36, and sends the package to reprographics to get copies made. Recall key punch only provides twenty-four copies of a mechanized PR. Reprographics sends all copies to MIPR Control. If the PR package includes an uncoordinated J&A, the competition manager must perform the same activities mentioned above. The division PR monitor sends the complete PR package to MIPR Control.

MIPR Control. PR/MIPR Control receives the PR package from either reprographics or the division PR monitor. See Figure 14. MIPR Control input the PR into a computer system and assemble the package for coordination.

After the coordination cycle, MIPR Control complete MM processing and send the PR package to PMXD.

PMXD. PMXD matches the history file and bidders list to the PR package and stamps the date on the PR. Then the "OO" card is input to the JO-18 computer system; this assigns the PR to a buying section and grants purchase authority.

Buying Sections. Two of the buying sections handle the PRs generated by the IMS. PMWFW buys wheel and brake items. Specifically, they buy items with a stock class of either 1630 or 2620 with a "LE" suffix. PMWFL buys landing gear items. Specifically, they buy items with a stock class of either 1620 or 5330 with a "LE" suffix.

Primary Determinants

The primary determinants were selected on the basis of their contribution estimates. The contribution estimates were calculated using both SLAM generated ALT and the Plackett and Burman design matrix. Variables 1, 4, 17, 27, 29, 31, and 33 were selected as the primary determinants. Table IV lists the selected variables with their descriptions; the range of values tested for each variable is in brackets.

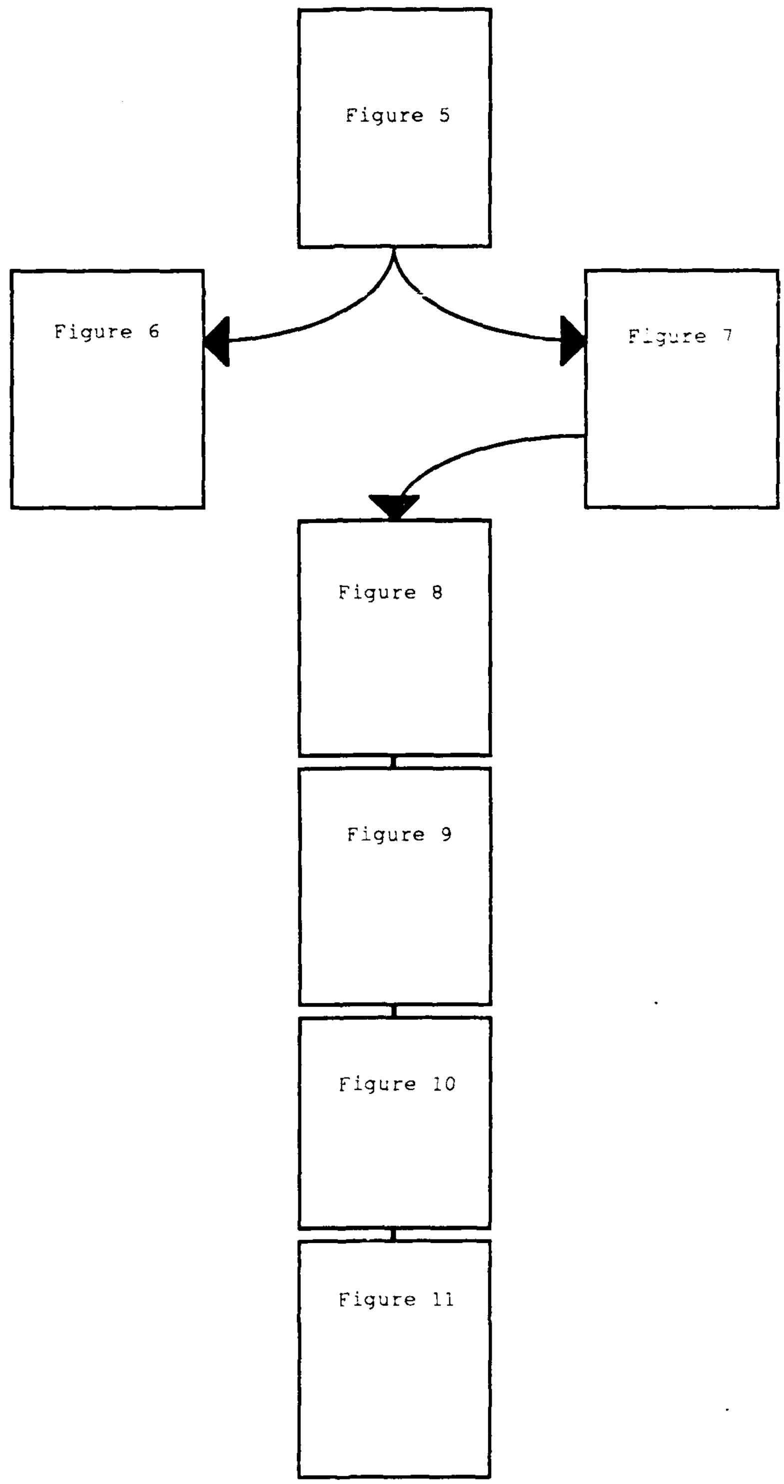

Figure 6: Ensemble of Figures 8 to 14

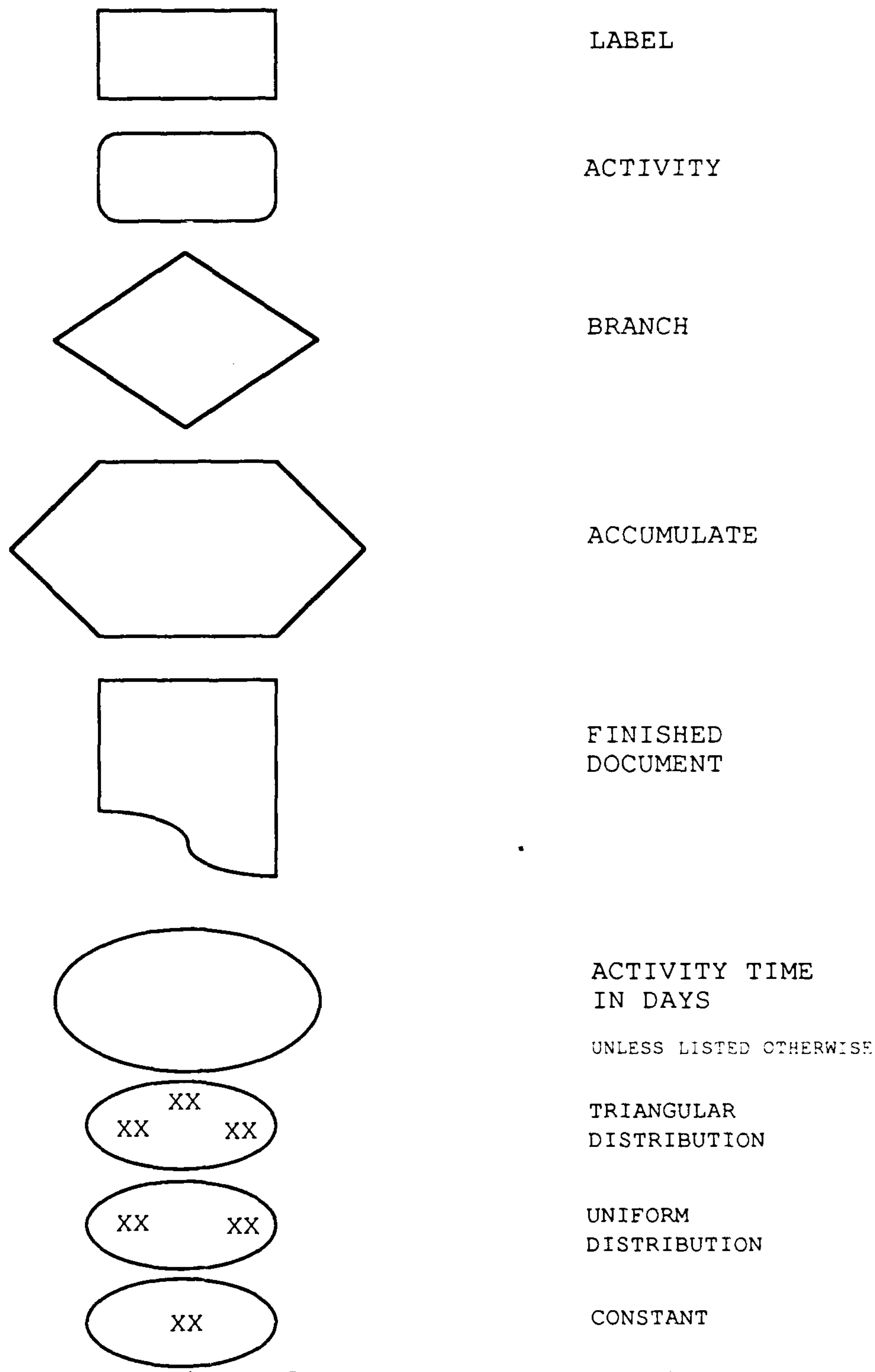

Figure 7: Key to Model Symbols

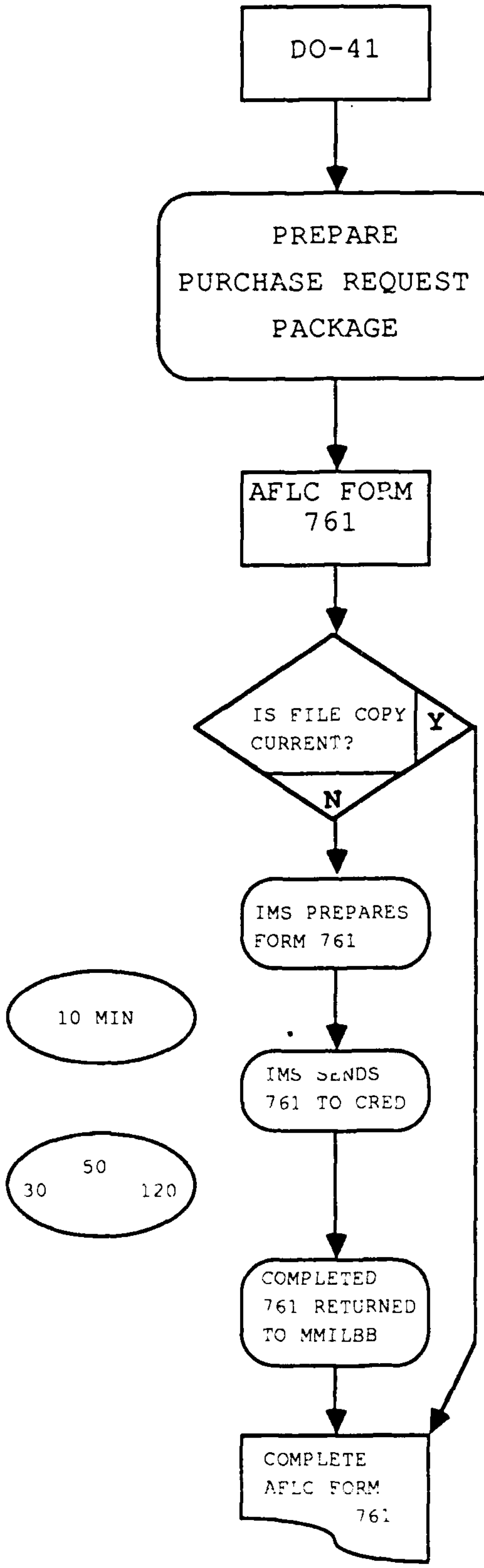

Figure 8: Model - Part 1

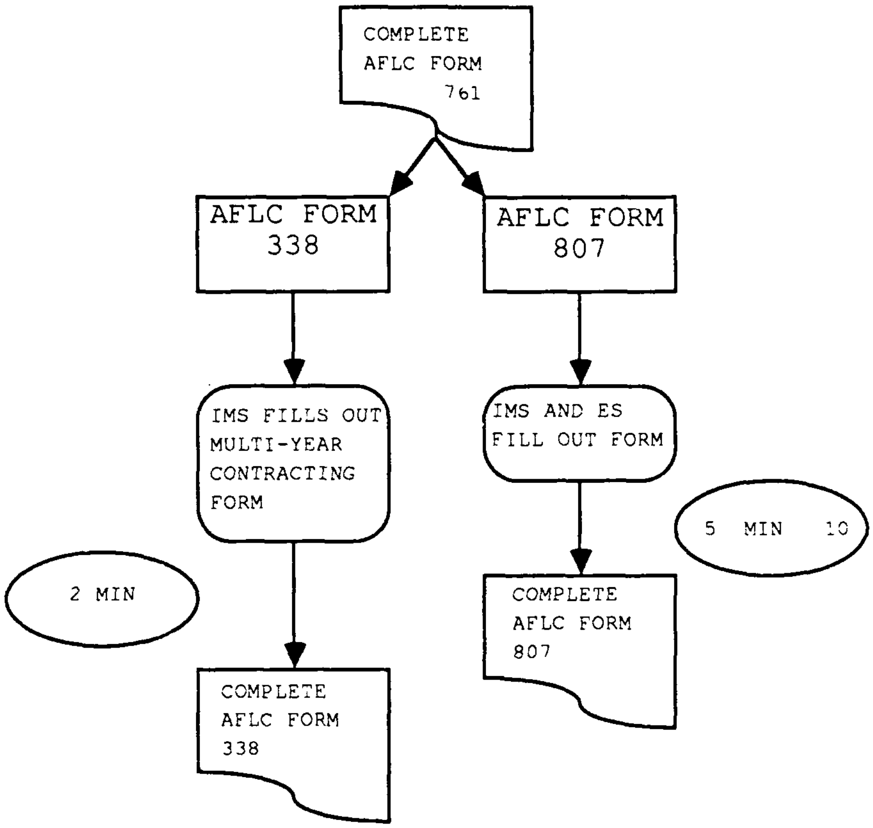

Figure 9: Model - Part 2a

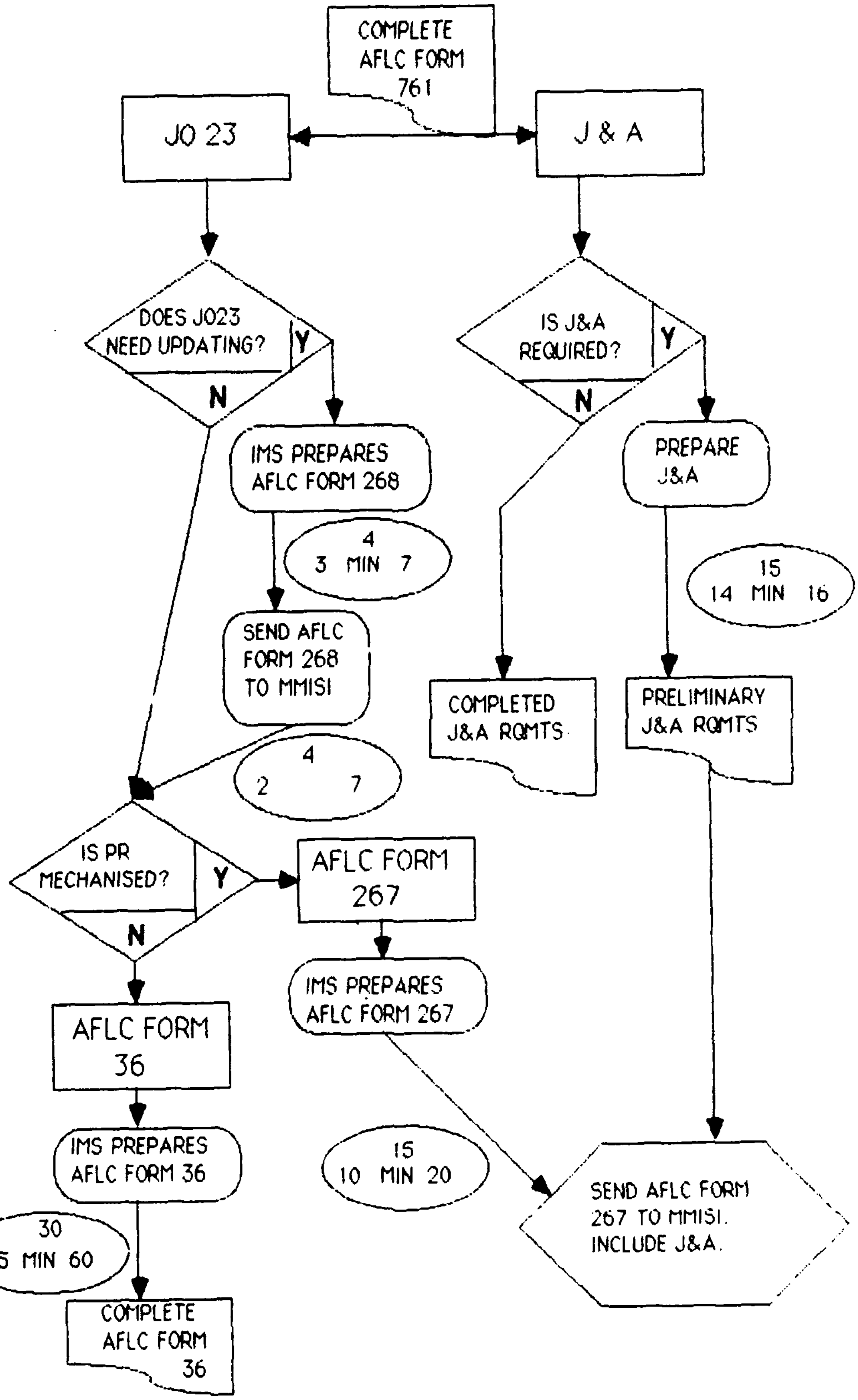

Figure 10: Model - Part 2b

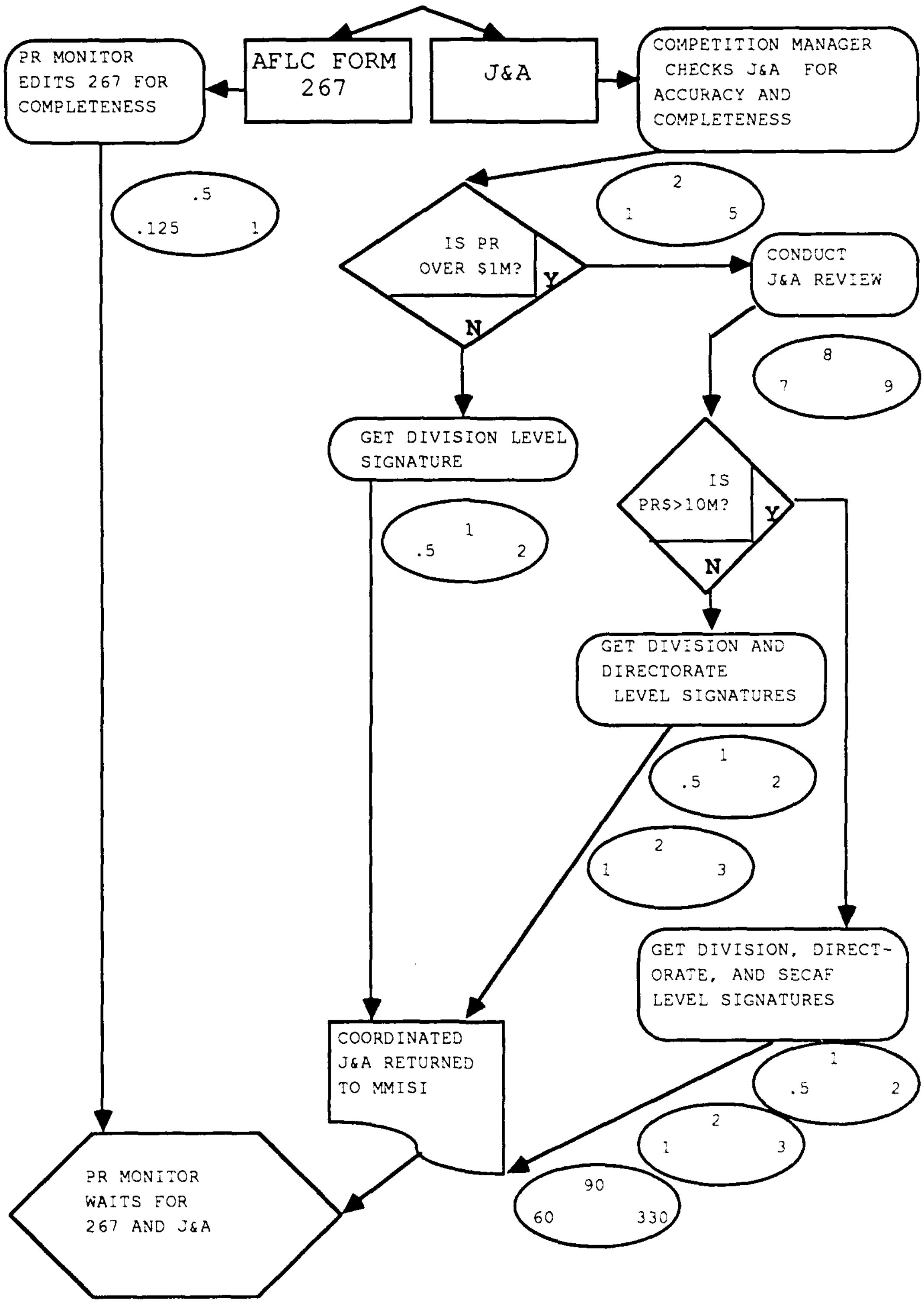

Figure 11: Model - Part 3

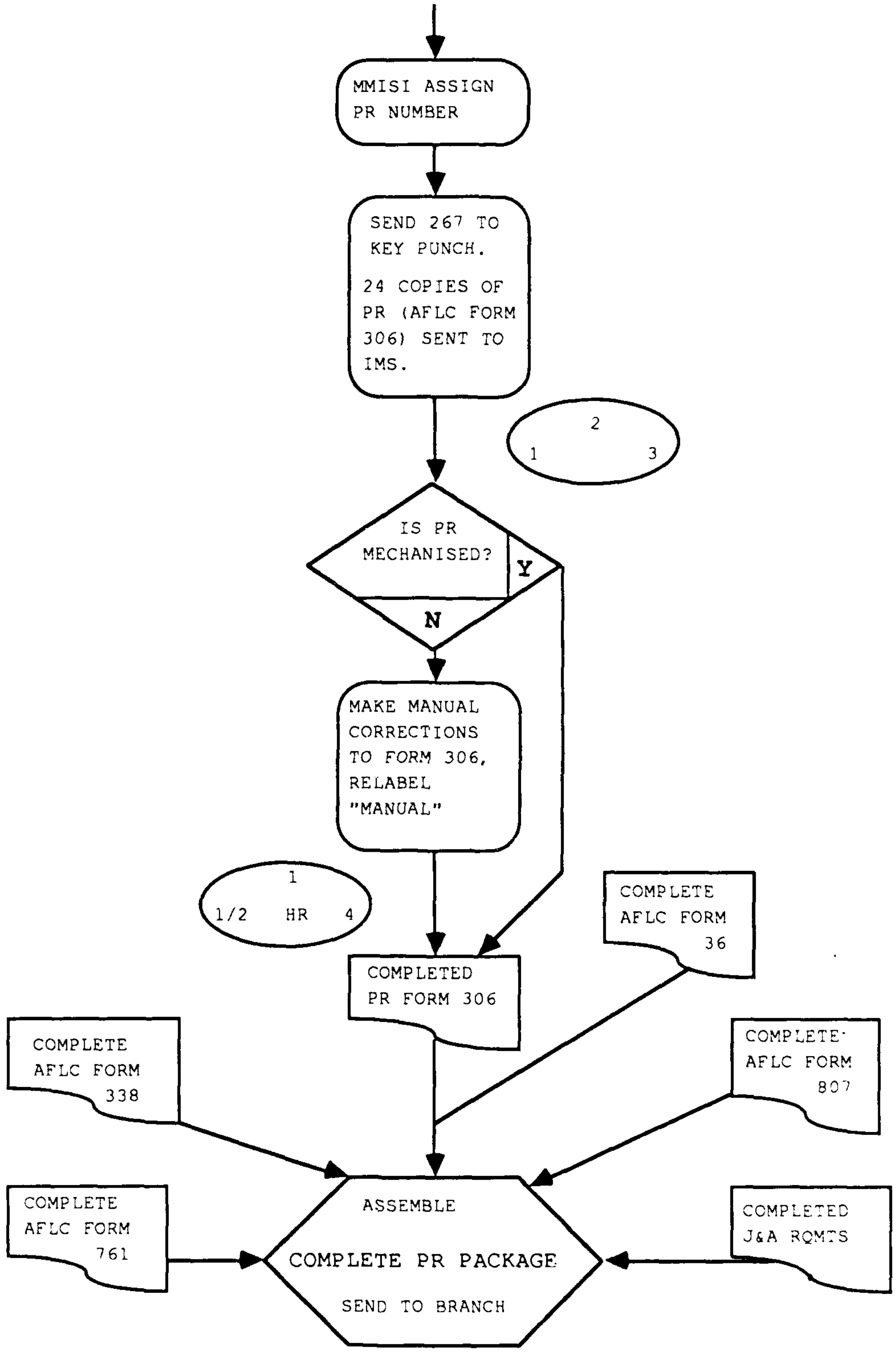

Figure 12: Model - Part 4

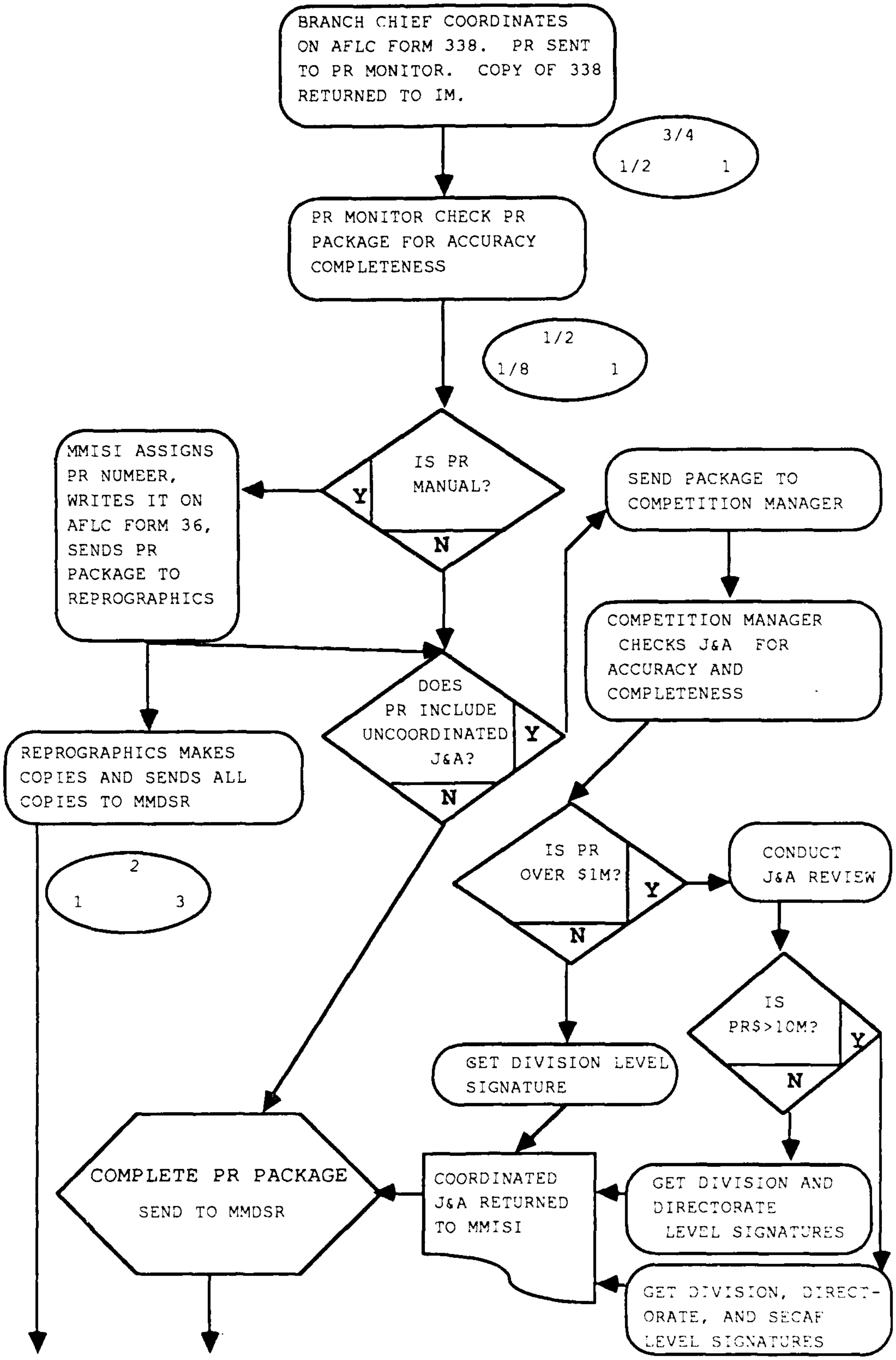

Figure 13: Model - Part 5

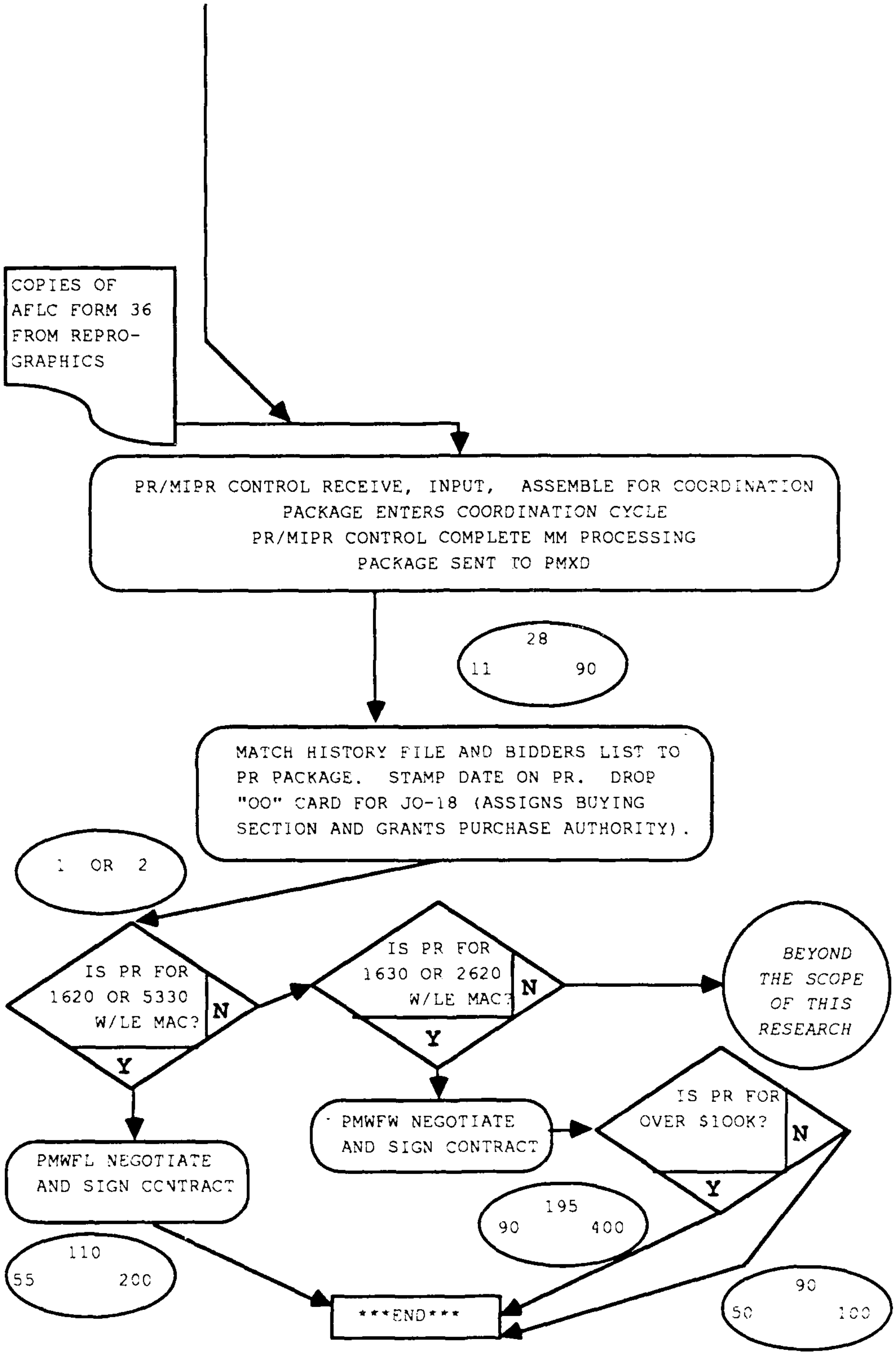

Figure 14: Model - Part 6

Table IV: Primary Determinants

XX(I)	Description
1	Probability of starting with an updated AFLC Form 761 (.9, .7)
4	Probability of no J&A requirement [1, .8]
17	Probability of J&A requiring SECAF coordination [.12, .16]
27	MIPR activity time [23, 33]
29	Probability of PR being wheels and brakes versus landing gear [.4, .6]
31	Probability of wheel and brake PR being less than $100K [.15, .05]
33	Activity time for wheel and brake PR over $100K [180, 210]

Metamodel

The metamodel was determined by using the SAS procedure PROC STEPWISE. The PROC STEPWISE looked at the seven primary determinants and their twenty-one possible two way interactions for a total of twenty-eight possible factors. A five variable model was chosen and it explains 98.22% of the SLAM model's variability. The following are the regression results from PROC STEPWISE.

Table V: Regression Results from Factor Screening

Variable	B Value	Std Error	F	Prob>F
Intercept	232.523			
XX(1)	6.369	.33665	357.91	.0001
XX(4)	2.043	.33665	36.82	.0001
XX(5)	10.063	.33665	893.54	.0001
XX(6)	3.356	.33665	99.41	.0001
XX(7)	2.303	.33665	46.81	.0001

The lack of fit test was done using these five variables. The following are the lack of fit test results.

Table VI: Lack of Fit Test Results

Residual	DF	Sum of Squares	Mean Square	F	Prob>F
Lack of Fit	27	95.2765	3.5288	1.295	.3672
Pure Error	9	24.5188	2.7243		
Total Error	36	119.7954			

The regression is based on coded variables i.e., one or minus one. To make more sense out of the regression, the variables must be decoded back to something meaningful.

Table VII: Decoded Variables

XX(I)	Real World Equivalent
1	(.8-P1)/.1
4	(A1-28)/5
5	(P2-.5)/.1
6	(.1-P3)/.05
7	(A2-195)/15

P1 = % of PRs needing no 761 update
A1 = Most likely MIPR activity time
P2 = % of PRs for wheels/brakes
P3 = % of PRs for wheels/brakes under $100K
A2 = Most likely PMWFW activity time for PRs over $100K

The metamodel then may be written substituting the real world equivalents for the experimental XX(I) variables. This model is only valid over the bracketted ranges.

$$ALT = 198.5 - 63.69\,(P1) + .4084\,(A1) + 100.63\,(P2) - 67.12\,(P3) + .153\,(A2) \qquad (1)$$

P1: [.9, .7]
A1: [23, 33]
P2: [.4, .6]
P3: [.15, .05]
A2: [180, 210]

V. Conclusions

Practical Implications

A significant result of this research is the procurement process has been analytically laid out. Managers and workers may start to look at the procurement system in a more informed way. The flow chart, figures 8 to 14, can be a useful tool to both new and experienced managers and workers. In fact, two experienced GS-11 Equipment Specialists from Ogden ALC MMILA requested to see the flow chart so they may better understand the process. The SLAM model provides the basis for experimentation to managers and new metamodels could be fitted using the experimental SLAM models.

As forewarned in the GAO report, competition has a time cost. Referencing Table 4, the first three primary determinants of ALT are all activities accomplished as a result of CICA. One of them, XX(1), appears in the metamodel as variable P1. A change from 80% to 90% will save 5.4 days on the average while a change from 80% to 70 % will cost 7.3 days.

It is not surprising for MIPR activity time to appear in the metamodel. Every PR must flow through MIPR so it makes sense if MIPR changes its activity time then ALT must change too. The last three elements of the metamodel pertain to PM. Since PMWFW activity time is greater than PMWFL activity time, the metamodel is sensitive to where

the PR is completed; this is variable P2 and has the highest coefficient in the metamodel. The metamodel is also sensitive to how many PMWFW PRs are under $100K because the activity time is much less. Finally, the metamodel is sensitive to the activity time for PMWFW PRs over $100K; this activity time is the longest in the entire acquisition process modeled.

There are three major organizations involved in the procurement process: MM, PM, and CR. It seems as if the system could be improved if MM would have more or all of its Forms 761 updated before a PR is initiated, if CR would process the Forms 761 faster, if MIPR Control would reduce their coordination cycle time, and if PM would reduce the time it takes to negotiate and sign a contract.

Recommendations for Revised Model

It would be interesting and useful to construct a metamodel for MM ALT. The SLAM model written for this research can provide MM ALT. During the group screening step of experimental design, only MM activities would be included in the Plackett and Burman design. The subsequent steps would follow accordingly.

Appendix A: Interviewees

NAME	Office Symbol	AUTOVON
Cambell, William	PMWFW	458-6292
Caravan, Elaine	MMDSR	458-7281
Chevez, Rick	MMILBB	458-5381
Clark, Karen	MMDS	458-4115
Cook, Jerry	PMXD	458-7357
Cottrell, Cal	PMWFW	458-6292
Evans, LaVae	MMILBB	458-7401
Lee, Richard	PMWFL	458-6501
Martinez, John	PMWFL	458-6501
Morrison, Connie	MMISI	458-4131
Rose, Sue	MMDSR	458-7281
Smith, Colleen	MMDS	458-4115

Appendix B: Basic SLAM Model Listing

```
GEN,DESILVA,BASE MODEL,7/10/89;
LIM,,4,25;
INTLC,XX(40)=0;
NETWORK;
CR1     CREATE,,,3;
        ASSIGN,ATRIB(1)=0,ATRIB(2)=0,XX(40)=XX(40)+1;
        ACT/1,,.8,PR1;
        ACT/2,TRIAG(30,50,120),.2,PR1;
PR1     COLCT,INT(3),TIME TO PROCESS 761,,5;
        ACT/3,,,PRP;
        ACT/4,.004,,PRP;
        ACT/5,UNFRM(.0104,.0208),,PRP;
        ACT/6,,,PR2;
        ACT/7,,.95,PR4;
        ACT/8,TRIAG(.029,.031,.033),.05,PR5;
PR2     GOON,1;
        ACT/9,,.98,PR3;
        ACT/10,TRIAG(.006,.008,.014),.02,NEXT;
NEXT    GOON,1;
        ACT/11,TRIAG(2,4,7);
PR3     GOON,1;
        ACT/12,TRIAG(.0208,.0312,.0416),.99,PRA;
        ACT/13,TRIAG(.0312,.0625,.125),.01,PR3A;
PR3A    ASSIGN,ATRIB(1)=1,2;
        ACT/14,,,PRP;
        ACT/15,,,PRM;
PRA     ASSIGN,ATRIB(1)=2;
        ACT/16,,,PRM;
PR4     ASSIGN,ATRIB(2)=1,ATRIB(3)=0,2;
        ACT/17,,,PRP;
        ACT/18,,,PRM;
PR5     ASSIGN,ATRIB(2)=2,ATRIB(3)=0;
PRM     ACCUM,2,2,SUM,2;
        ACT/19,,ATRIB(2).EQ.1,PR7;
        ACT/20,,ATRIB(1).EQ.1,PR7;
        ACT/21,,ATRIB(1).EQ.2,PR6;
        ACT/22,,ATRIB(2).EQ.2,CM;
CM      COLCT,INT(3),CM,,1;
        ACT/23,TRIAG(1,2,5);
        GOON;
        ACT/24,TRIAG(.5,1,2);
        GOON,1;
        ACT/25,,.77,PR7;
        ACT/26,TRIAG(7,8,9),.23;
        GOON;
        ACT/27,TRIAG(1,2,3);
        GOON,1;
        ACT/28,,.86,PR7;
        ACT/29,TRIAG(60,90,330),.14,PR7;
PR6     GOON,1;
```

```
        ACT/30,TRIAG(.125,.5,1),,PR7;
PR7     ACCUM,2,2,3;
        ACT/31,,ATRIB(2).EQ.2,PRP;
        ACT/32,TRIAG(1,2,3),ATRIB(1).EQ.2,PR7A;
        ACT/50,,ATRIB(1).EQ.1,TERM;
PR7A    GOON,1;
        ACT/33,,.85,PRP;
        ACT/34,TRIAG(.0625,.125,.5),.15,PRP;
PRP     ACCUM,5,5;
        COLCT,INT(3),PRP,,1;
        ACT/35,TRIAG(.5,.75,1);
        GOON;
        ACT/36,TRIAG(.125,.5,1);
        GOON,1;
        ACT/37,TRIAG(1,2,3),.4,MIPR;
        ACT/38,,.6,MIPR;
MIPR    GOON;
        ACT/39,TRIAG(11,28,90);
        COLCT,INT(3),MM ALT,,1;
        ACT/40,1,.7,BUY;
        ACT/41,2,.3,BUY;
BUY     GOON,1;
        ACT/42,,.5,WB;
        ACT/43,TRIAG(55,110,200),.5,REDO;
WB      GOON,1;
        ACT/44,TRIAG(50,90,100),.1,REDO;
        ACT/45,TRIAG(100,195,400),.9,REDO;
        ACT/46,XX(40).LT.1500,CR1;
        ACT/47;
TERM    TERM;
        ENDNETWORK;
INIT;
FIN;
```

Appendix C: SLAM2 Batch File Listing for PC SLAM

```
echo off
echo * slam batch program    Ignore the "File not found"
message
rem * by Chris Hall GSE-88d  Feb 88  Box 4408
:start
if "%1"=="" goto done
if exist %1 goto usage
if not exist %1.dat goto nofile
for %%e in (tra out rpt) do del %1.%%e
echo %1.dat >  %1
echo %1.tra >> %1
echo input %1.dat %1.tra
input <%1 >>%1.tmp
if not exist %1.tra goto ierr
echo %1.tra >  %1
echo %1.out >> %1
echo executio %1.tra %1.out
executio <%1 >>%1.tmp
if not exist %1.out goto eerr
echo %1.out >  %1
echo 1 >> %1
echo 2 >> %1
echo %1.rpt >> %1
echo 12 >> %1
echo output %1.out %1.rpt
output <%1 >>%1.tmp
if not exist %1.rpt goto oerr
erase %1
for %%e in (tra out) do del %1.%%e
shift
goto start
:nofile
echo %1.dat not found; continuing...
shift
goto start
:oerr
echo error processing data file %1.out
del %1
goto done
:eerr
echo error processing model file %1.tra
del %1
goto done
:ierr
echo error processing input file %1.dat
del %1
goto done
:usage
echo * usage:  SLAM2 filename without extension
echo *
```

Appendix D: SLAM Model Listing for Factor Screening

```
GEN,DESILVA,GROUP SCREENING MODEL,7/10/89,36;
LIM,,4,25;
INTLC,XX(40)=0;
NETWORK;
CR1     CREATE,,,3;
        ASSIGN,ATRIB(1)=0,ATRIB(2)=0,XX(40)=XX(40)+1;
        ACT/1,,XX(1),PR1;
        ACT/2,TRIAG(30,XX(2),120),1-XX(1),PR1;
PR1     COLCT,INT(3),TIME TO PROCESS 761,,5;
        ACT/3,,,PRP;
        ACT/4,.004,,PRP;
        ACT/5,UNFRM(XX(3),2*XX(3)),,PRP;
        ACT/6,,,PR2;
        ACT/7,,XX(4),PR4;
        ACT/8,TRIAG(.029,XX(5),.033),1-XX(4),PR5;
PR2     GOON,1;
        ACT/9,,XX(6),PR3;
        ACT/10,TRIAG(.006,XX(7),.014),1-XX(6),NEXT;
NEXT    GOON,1;
        ACT/11,TRIAG(2,XX(8),7);
PR3     GOON,1;
        ACT/12,TRIAG(.0208,XX(10),.0416),XX(9),PRA;
        ACT/13,TRIAG(.0312,XX(11),.125),1-XX(9),PR3A;
        ACT/14,,,PRP;
        ACT/15,,,PRM;
PRA     ASSIGN,ATRIB(1)=2;
        ACT/16,,,PRM;
PR4     ASSIGN,ATRIB(2)=1,ATRIB(3)=0,2;
        ACT/17,,,PRP;
        ACT/18,,,PRM;
PR5     ASSIGN,ATRIB(2)=2,ATRIB(3)=0;
PRM     ACCUM,2,2,SUM,2;
        ACT/19,,ATRIB(2).EQ.1,PR7;
        ACT/20,,ATRIB(1).EQ.1,PR7;
        ACT/21,,ATRIB(1).EQ.2,PR6;
        ACT/22,,ATRIB(2).EQ.2,CM;
CM      COLCT,INT(3),CM,,1;
        ACT/23,TRIAG(1,XX(12),5);
        GOON;
        ACT/24,TRIAG(.5,XX(13),2);
        GOON,1;
        ACT/25,,1-XX(14),PR7;
        ACT/26,TRIAG(7,XX(15),9),XX(14);
        GOON;
        ACT/27,TRIAG(1,XX(16),3);
        GOON,1;
        ACT/28,,1-XX(17),PR7;
        ACT/29,TRIAG(60,XX(18),330),XX(17),PR7;
PR6     GOON,1;
        ACT/30,TRIAG(.125,XX(19),1),,PR7;
PR7     ACCUM,2,2,3;
```

```
        ACT/31,,ATRIB(2).EQ.2,PRP;
        ACT/32,TRIAG(1,XX(20),3),ATRIB(1).EQ.2,PR7A;
        ACT/50,,ATRIB(1).EQ.1,TERM;
PR7A    GOON,1;
        ACT/33,,XX(21),PRP;
        ACT/34,TRIAG(.0625,XX(22),.5),1-XX(21),PRP;
PRP     ACCUM,5,5;
        COLCT,INT(3),PRP,,1;
        ACT/35,TRIAG(.5,XX(23),1);
        GOON;
        ACT/36,TRIAG(.125,XX(24),1);
        GOON,1;
        ACT/37,TRIAG(1,XX(26),3),XX(25),MIPR;
        ACT/38,,1-XX(25),MIPR;
MIPR    GOON;
        ACT/39,TRIAG(11,XX(27),90);
        COLCT,INT(3),MM ALT,,1;
        ACT/40,1,XX(28),BUY;
        ACT/41,2,1-XX(28),BUY;
BUY     GOON,1;
        ACT/42,,XX(29),WB;
        ACT/43,TRIAG(55,XX(30),200),1-XX(29),REDO;
WB      GOON,1;
        ACT/44,TRIAG(50,XX(32),100),XX(31),REDO;
        ACT/45,TRIAG(100,XX(33),400),1-XX(31),REDO;
        ACT/46,XX(40).LT.1500,CR1;
        ACT/47;
TERM    TERM;
        ENDNETWORK;
INIT;
FIN;
```

Appendix E: <u>Fortran Insert Listing for Factor Screening</u>

```
PROGRAM MAIN
DIMENSION NSET(10000)
INCLUDE 'SLAM$DIR:PARAM.INC'
COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
SSL(100),TNEXT,TNOW,XX(100)
COMMON QSET(10000)
EQUIVALENCE (NSET(1),QSET(1))
OPEN (UNIT=10, FILE='TEST.FIL',STATUS = 'OLD')
OPEN (UNIT=11, FILE='OUTPUT',STATUS = 'NEW')
NNSET=10000
NCRDR=5
NPRNT=6
NTAPE=7
NPLOT=2
CALL SLAM
STOP
END

SUBROUTINE OTPUT
INCLUDE 'SLAM$DIR:PARAM.INC'
WRITE(11,*)CCAVG(5),CCAVG(6)
RETURN
END

SUBROUTINE INTLC
INCLUDE 'SLAM$DIR:PARAM.INC'
COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
SSL(100),TNEXT,TNOW,XX(100)
INTEGER D(33)
READ(10,*) (D(I),I=1,33)
IF (D(1).EQ.-1) XX(1)=.9
IF (D(1).EQ.1) XX(1)=.7
IF (D(2).EQ.-1) XX(2)=40
IF (D(2).EQ.1) XX(2)=85
IF (D(3).EQ.-1) XX(3)=.004
IF (D(3).EQ.1) XX(3)=.0208
IF (D(4).EQ.-1) XX(4)=1
IF (D(4).EQ.1) XX(4)=.8
IF (D(5).EQ.-1) XX(5)=.03
IF (D(5).EQ.1) XX(5)=.032
IF (D(6).EQ.-1) XX(6)=1
IF (D(6).EQ.1) XX(6)=.96
IF (D(7).EQ.-1) XX(7)=.007
IF (D(7).EQ.1) XX(7)=.012
IF (D(8).EQ.-1) XX(8)=3
IF (D(8).EQ.1) XX(8)=5
IF (D(9).EQ.-1) XX(9)=.95
IF (D(9).EQ.1) XX(9)=1
IF (D(10).EQ.-1) XX(10)=.0271
```

```
IF (D(10).EQ.1) XX(10)=.0354
IF (D(11).EQ.-1) XX(11)=.0416
IF (D(11).EQ.1) XX(11)=.0937
IF (D(12).EQ.-1) XX(12)=1.5
IF (D(12).EQ.1) XX(12)=2.5
IF (D(13).EQ.-1) XX(13)=.75
IF (D(13).EQ.1) XX(13)=1.25
IF (D(14).EQ.-1) XX(14)=.2
IF (D(14).EQ.1) XX(14)=.25
IF (D(15).EQ.-1) XX(15)=7.5
IF (D(15).EQ.1) XX(15)=8.5
IF (D(16).EQ.-1) XX(16)=1.5
IF (D(16).EQ.1) XX(16)=2.5
IF (D(17).EQ.-1) XX(17)=.12
IF (D(17).EQ.1) XX(17)=.16
IF (D(18).EQ.-1) XX(18)=75
IF (D(18).EQ.1) XX(18)=120
IF (D(19).EQ.-1) XX(19)=.25
IF (D(19).EQ.1) XX(19)=.75
IF (D(20).EQ.-1) XX(20)=1.5
IF (D(20).EQ.1) XX(20)=2.5
IF (D(21).EQ.-1) XX(21)=.9
IF (D(21).EQ.1) XX(21)=.8
IF (D(22).EQ.-1) XX(22)=.0937
IF (D(22).EQ.1) XX(22)=.1875
IF (D(23).EQ.-1) XX(23)=.625
IF (D(23).EQ.1) XX(23)=.875
IF (D(24).EQ.-1) XX(24)=.25
IF (D(24).EQ.1) XX(24)=.75
IF (D(25).EQ.-1) XX(25)=.3
IF (D(25).EQ.1) XX(25)=.5
IF (D(26).EQ.-1) XX(26)=1.5
IF (D(26).EQ.1) XX(26)=2.5
IF (D(27).EQ.-1) XX(27)=23
IF (D(27).EQ.1) XX(27)=33
IF (D(28).EQ.-1) XX(28)=.8
IF (D(28).EQ.1) XX(28)=.7
IF (D(29).EQ.-1) XX(29)=.4
IF (D(29).EQ.1) XX(29)=.6
IF (D(30).EQ.-1) XX(30)=100
IF (D(30).EQ.1) XX(30)=120
IF (D(31).EQ.-1) XX(31)=.15
IF (D(31).EQ.1) XX(31)=.05
IF (D(32).EQ.-1) XX(32)=85
IF (D(32).EQ.1) XX(32)=95
IF (D(33).EQ.-1) XX(33)=180
IF (D(33).EQ.1) XX(33)=210
RETURN
END
```

Appendix F: SLAM Model Listing for First Order Linear Metamodel

```
GEN,DESILVA,FACTOR SCREENING MODEL,7/10/89,32;
LIM,,4,25;
INTLC,XX(40)=0;
NETWORK;
CR1     CREATE,,,3;
        ASSIGN,ATRIB(1)=0,ATRIB(2)=0,XX(40)=XX(40)+1;
        ACT/1,,XX(1),PR1;
        ACT/2,TRIAG(30,50,120),1-XX(1),PR1;
PR1     COLCT,INT(3),TIME TO PROCESS 761,,5;
        ACT/3,,,PRP;
        ACT/4,.004,,PRP;
        ACT/5,UNFRM(.0104,.0208),,PRP;
        ACT/6,,,PR2;
        ACT/7,,XX(2),PR4;
        ACT/8,TRIAG(.029,.031,.033),1-XX(2),PR5;
PR2     GOON,1;
        ACT/9,,.98,PR3;
        ACT/10,TRIAG(.006,.008,.014),.02,NEXT;
NEXT    GOON,1;
        ACT/11,TRIAG(2,4,7);
PR3     GOON,1;
        ACT/12,TRIAG(.0208,.0312,.0416),.99,PRA;
        ACT/13,TRIAG(.0312,.0625,.125),.01,PR3A;
PR3A    ASSIGN,ATRIB(1)=1,2;
        ACT/14,,,PRP;
        ACT/15,,,PRM;
PRA     ASSIGN,ATRIB(1)=2;
        ACT/16,,,PRM;
PR4     ASSIGN,ATRIB(2)=1,ATRIB(3)=0,2;
        ACT/17,,,PRP;
        ACT/18,,,PRM;
PR5     ASSIGN,ATRIB(2)=2,ATRIB(3)=0;
PRM     ACCUM,2,2,SUM,2;
        ACT/19,,ATRIB(2).EQ.1,PR7;
        ACT/20,,ATRIB(1).EQ.1,PR7;
        ACT/21,,ATRIB(1).EQ.2,PR6;
        ACT/22,,ATRIB(2).EQ.2,CM;
CM      COLCT,INT(3),CM,,1;
        ACT/23,TRIAG(1,2,5);
        GOON;
        ACT/24,TRIAG(.5,1,2);
        GOON,1;
        ACT/25,,.77,PR7;
        ACT/26,TRIAG(7,8,9),.23;
        GOON;
        ACT/27,TRIAG(1,2,3);
        GOON,1;
        ACT/28,,1-XX(3),PR7;
        ACT/29,TRIAG(60,90,330),XX(3),PR7;
PR6     GOON,1;
```

```
        ACT/30,TRIAG(.125,.5,1),,PR7;
PR7     ACCUM,2,2,3;
        ACT/31,,ATRIB(2).EQ.2,PRP;
        ACT/32,TRIAG(1,2,3),ATRIB(1).EQ.2,PR7A;
        ACT/50,,ATRIB(1).EQ.1,TERM;
PR7A    GOON,1;
        ACT/33,,.85,PRP;
        ACT/34,TRIAG(.0625,.125,.5),.15,PRP;
PRP     ACCUM,5,5;
        COLCT,INT(3),PRP,,1;
        ACT/35,TRIAG(.5,.75,1);
        GOON;
        ACT/36,TRIAG(.125,.5,1);
        GOON,1;
        ACT/37,TRIAG(1,2,3),.4,MIPR;
        ACT/38,,.6,MIPR;
MIPR    GOON;
        ACT/39,TRIAG(11,XX(4),90);
        COLCT,INT(3),MM ALT,,1;
        ACT/40,1,.7,BUY;
        ACT/41,2,.3,BUY;
BUY     GOON,1;
        ACT/42,,XX(5),WB;
        ACT/43,TRIAG(55,110,200),1-XX(5),REDO;
WB      GOON,1;
        ACT/44,TRIAG(50,90,100),XX(6),REDO;
        ACT/45,TRIAG(100,XX(7),400),1-XX(6),REDO;
        ACT/46,XX(40).LT.1500,CR1;
        ACT/47;
TERM    TERM;
        ENDNETWORK;
INIT;
FIN;
```

Appendix G: Fortran Insert Listing for First Order Linear Metamodel

```
PROGRAM MAIN
DIMENSION NSET(10000)
INCLUDE 'SLAM$DIR:PARAM.INC'
COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA,
MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
SSL(100),TNEXT,TNOW,XX(100)
COMMON QSET(10000)
EQUIVALENCE (NSET(1),QSET(1))
OPEN (UNIT=10, FILE='TEST.FIL',STATUS = 'OLD')
OPEN (UNIT=11, FILE='OUTPUT',STATUS = 'NEW')
NNSET=10000
NCRDR=5
NPRNT=6
NTAPE=7
NPLOT=2
CALL SLAM
STOP
END

SUBROUTINE OTPUT
INCLUDE 'SLAM$DIR:PARAM.INC'
WRITE(11,*)CCAVG(5),CCAVG(6)
RETURN
END

SUBROUTINE INTLC
INCLUDE 'SLAM$DIR:PARAM.INC'
COMMON/SCOM1/ATRIB(100),DD(100),DDL(100),DTNOW,II,MFA
MSTOP,NCLNR,NCRDR,NPRNT,NNRUN,NNSET,NTAPE,SS(100),
SSL(100),TNEXT,TNOW,XX(100)
INTEGER D(7)
READ(10,*) (D(I),I=1,7)
IF (D(1).EQ.-1) XX(1)=.9
IF (D(1).EQ.1) XX(1)=.7
IF (D(2).EQ.-1) XX(2)=1
IF (D(2).EQ.1) XX(2)=.8
IF (D(3).EQ.-1) XX(3)=.12
IF (D(3).EQ.1) XX(3)=.16
IF (D(4).EQ.-1) XX(4)=23
IF (D(4).EQ.1) XX(4)=33
IF (D(5).EQ.-1) XX(5)=.4
IF (D(5).EQ.1) XX(5)=.6
IF (D(6).EQ.-1) XX(6)=.15
IF (D(6).EQ.1) XX(6)=.05
IF (D(7).EQ.-1) XX(7)=180
IF (D(7).EQ.1) XX(7)=210
RETURN
END
```

Appendix H: SAS Input Listing for PROC STEPWISE

```
DATA TEST2SAS;
   INPUT VAR1 VAR2 VAR3 VAR4 VAR5 VAR6
   VAR7 VAR8 VAR9 VAR10 VAR11 VAR12 VAR13
   VAR14 VAR15 VAR16 VAR17 VAR18 VAR19
   VAR20 VAR21 VAR22 VAR23 VAR24 VAR25
   VAR26 VAR27 VAR28 ALT @@;
   CARDS;
[Same design matrix as appendix I except extra columns for
two-way interactions and no runs at zero]
;
PROC STEPWISE;
   MODEL ALT=VAR1 VAR2 VAR3 VAR4 VAR5 VAR6
   VAR7 VAR8 VAR9 VAR10 VAR11 VAR12 VAR13
   VAR14 VAR15 VAR16 VAR17 VAR18 VA19 VAR20
   VAR21 VAR22 VAR23 VAR24 VAR25 VAR26
   VAR27 VAR28/FORWARD BACKWARD STEPWISE;
```

Appendix I: SAS Input Listing for PROC RSREG

```
DATA RSREG;
   INPUT VAR1 VAR2 VAR3 VAR4 VAR5 VAR6 VAR7 ALT @@;
   CARDS;
-1 -1 -1 -1 -1  1  1 219.50
 1 -1 -1 -1 -1 -1 -1 223.00
-1  1 -1 -1 -1 -1 -1 208.30
 1  1 -1 -1 -1  1  1 233.40
-1 -1  1 -1 -1 -1 -1 209.42
 1 -1  1 -1 -1  1  1 227.96
-1  1  1 -1 -1  1  1 220.07
 1  1  1 -1 -1 -1 -1 221.69
-1 -1 -1  1 -1 -1  1 215.65
 1 -1 -1  1 -1  1 -1 233.90
-1  1 -1  1 -1  1 -1 217.90
 1  1 -1  1 -1 -1  1 230.50
-1 -1  1  1 -1  1 -1 219.61
 1 -1  1  1 -1 -1  1 229.00
-1  1  1  1 -1 -1  1 217.86
 1  1  1  1 -1  1 -1 231.55
-1 -1 -1 -1  1  1 -1 234.70
 1 -1 -1 -1  1 -1  1 246.18
-1  1 -1 -1  1 -1  1 235.84
 1  1 -1 -1  1  1 -1 246.15
-1 -1  1 -1  1 -1  1 231.76
 1 -1  1 -1  1  1 -1 246.88
-1  1  1 -1  1  1 -1 237.87
 1  1  1 -1  1 -1  1 244.94
-1 -1 -1  1  1 -1 -1 228.48
 1 -1 -1  1  1  1  1 258.21
-1  1 -1  1  1  1  1 246.45
 1  1 -1  1  1 -1 -1 247.35
-1 -1  1  1  1  1  1 242.18
 1 -1  1  1  1 -1 -1 243.80
-1  1  1  1  1 -1 -1 232.90
 1  1  1  1  1  1  1 257.70
 0  0  0  0  0  0  0 234.31
 0  0  0  0  0  0  0 233.37
 0  0  0  0  0  0  0 234.96
 0  0  0  0  0  0  0 233 74
 0  0  0  0  0  0  0 230.58
 0  0  0  0  0  0  0 232.65
 0  0  0  0  0  0  0 235.03
 0  0  0  0  0  0  0 232.02
 0  0  0  0  0  0  0 231.98
 0  0  0  0  0  0  0 230.50
;
PROC RSREG;
   MODEL ALT=VAR1 VAR4 VAR5 VAR6 VAR7/LACKFIT COVAR=5;
```

Appendix J: DO-41 ALT

Pre-PR Processing	PR Coordination	Procurement ALT
146	27	214
210	29	126
264	37	92
205	20	162
264	37	85
141	33	114
89	29	76
154	91	147
91	20	107
109	25	90
132	15	74
137	25	80
145	41	51
151	28	58
151	28	64
106	12	149
89	36	140
113	27	116
120	46	98
120	46	86
124	23	98
124	23	113
141	20	92
151	28	84
151	30	72
66	42	382
70	17	285
49	28	118
54	49	100
81	35	108
81	35	95
34	31	70
43	19	176
36	21	201
54	43	142
54	45	154
63	41	145
51	1	20
68	1	20
54	23	187
69	40	165
81	24	162
83	44	147
127	27	125
154	39	94
111	2	182
111	79	115
67	25	208

Pre-PR Processing	PR Coordination	Procurement ALT
119	22	158
79	11	24
50	21	43
34	23	251
81	157	64
51	61	90
43	41	128
47	65	100

Bibliography

1. Adams, John R. and Martin, M. Dean. Professional Project Management A Practical Guide. Dayton: Universal Technology Corporation, 1987.

2. Bauer, K. W. Class handout distributed in OPER 750, Response Surface Methodology. School of Engineering, Air Force Institute of Technology (AU), Wright-Patterson AFB OH, August 1989.

3. Biles, William E. "INTRODUCTION TO SIMULATION," Proceedings of the 1987 Winter Simulation Conference. 7-8.

4. Blanchard, Benjamin S. and Fabrycky, Wolter J. Systems Engineering and Analysis. Englewood Cliffs: Prentice-Hall Inc., 1981.

5. Box, George E.P. and Draper, Norman R. EMPIRICAL MODEL-BUILDING AND RESPONSE SURFACES. New York: John Wiley & Sons, 1987.

6. Cambell, William, Principal Contracting Officer. Personal Interview. Hill AFB UT, 23 June 1989.

7. Caravan, Elaine, PR Clerk. Telephone Interview. Hill AFB UT, 10 January 1989.

8. Chevez, Rick, Item Management Specialist. Personal Interview. Hill AFB UT, 20 June through 23 June 1989.

9. Chevez, Rick, PR Monitor. Telephone Interview. Hill AFB UT, 9 January 1989.

10. Cook, Jerry, PR Clerk. Personal Interview. Hill AFB UT, 22 June 1989.

11. Cook, Jerry, PR Clerk. Telephone Interview. Hill AFB UT, 23 January 1989.

12. Cottrell, Cal, Section Chief, PMWFW. Telephone Interview. Hill AFB UT, 31 January 1989.

13. Evans, LaVae, Item Management Specialist. Personal Interview. Hill AFB UT, 20 June through 23 June 1989.

14. Evans, LaVae, Item Management Specialist. Telephone Interview. Hill AFB UT, 6 January 1989.

15. General Accounting Office. DOD Initiatives to Improve Acquisition of Spare Parts. Report No. 86-52. Washington: Government Printing Office, 1986.

16. Lee, Richard, Principal Contracting Officer. Personal Interview. Hill AFB UT, 23 June 1989.

17. Martinez, John, Section Chief, PMWFL. Telephone Interview. Hill AFB UT, 31 January 1989.

18. Morrison, Connie, Competition Manager. Personal Interview. Hill AFB UT, 29 June 1989.

19. Pritsker, A. Alan B. Introduction to Simulation and SLAM II. West Lafayette: Systems Publishing Corporation, 1986.

20. Rose, Sue, Supervisor, PR/MIPR Control. Personal Interview. Hill AFB UT, 22 June 1989.

21. Schonberger, Richard J. and Knod, Edward M. Management Serving the Customer. Homewood: Business Publications Inc., 1988.

22. U.S. Congress. Competition in Contracting Act of 1984. Public Law No. 369, 98th Congress, 2nd Session. Washington: Government Printing Office, 1984.

23. Winston, Wayne L. Operations Research: Applications and Algorithms. Boston: PWS Publishers, 1987.

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The purpose of this ~~research~~ was to describe the spare parts procurement process at Ogden ALC UT in terms of adminstrative lead time. Specifically, this research describes the process from MMILBB to either PMWFW or PMWFL. The process was described in three ways. A flow chart depicting the flow of paperwork and associated activity times was constructed. This was translated into a SLAM network diagram and then into SLAM computer code. The computer code was used to experiment with the procurement system by varying the activity times and branching probabilities. The important parameters were then used to construct a metamodel, an equation that describes the SLAM model of the procurment system. Within MM, the metamodel is sensitive to the percentage of Forms 761 that need to be updated, to MIPR Control activity time, to the percentage of PRs going to PMWFW instead of PMWFL, and to the percentage of PRs under $100K going to PMWFW. Within PM, the metamodel is sensitive to activity time in PMWFW for PRs over $100K.